GREEN CERTIFICATION PATHWAYS: THE ROLES OF PUBLIC GOODS, PRIVATE GOODS, AND CERTIFICATION SCHEMES

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GREEN CERTIFICATION PATHWAYS: THE ROLES OF PUBLIC GOODS, PRIVATE GOODS, AND CERTIFICATION SCHEMES

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LIST OF ABBREVIATIONS

AP	Associated Professional (LEED / USGBC affiliated)
BRE	British Real Estate (Ratings Agency)
CSR	Corporate Social Responsibility
EA	Energy and Atmosphere
EPA	(US) Environmental Protection Agency
FWER	Family-Wise Error Rate
Gov.	Government owner
ISO 14001	International Organization for Standardization
KLD	*KLD* Research & Analytics Group: Social Responsibility Index
LEED	Leadership in Energy and Environmental Design
NMSD	Non-State Market-Driven (Governance)
OLS	Ordinary Least Squares (Regression Method)
ROI	Return on Investment
RTB	Race to the Bottom (interchangeably, Race to the Bar)
RTT	Race to the Top
USGBC	United States Green Building Council
VOC	Volatile Organic Compound
WE	Water Efficiency

SUMMARY

This dissertation examines evidence on the effectiveness of voluntary certification programs in the built environment. Drawing on unique data from buildings certified under the Leadership in Energy and Environmental Design (LEED) label, the technologies adopted toward certification are examined. Analysis reveals strengths and weaknesses of the program design, including apparent promotion of energy and water efficiency, but limited promotion of public good provision. These findings motivate extensive theoretical development around the valuation of environmental products: traditional economic signaling perspectives are argued to be of little value in understanding "noisy" signals of environmental quality. Drawing on perspectives from organizational theory and strategic management, a framework for noisy signals is developed, and applied to three empirical questions. First, the extent to which noisy signals are strategically adopted is examined by assessing patterns in technology adoption toward green building certification. Second, the evolving distribution of LEED scores is assessed against a dynamic imputed counterfactual to reveal the extent to which the certification fosters a "Race to the Top." Here, signaling and learning are posited as a mechanism for such a "Race," in a critique of past theory. Finally, the shift in practices contributing from public goods to private gains is evaluated over time, calling to question how we should measure the success of environmental programs which aim to promote improvements with regard to myriad concerns. In sum, this work contributes to our understanding of corporate sustainability, certification programs, signaling theory, and technology learning.

CHAPTER 1: INTRODUCTION

This introduction presents an overview of green building economics through a survey of the theoretical and empirical evidence concerning green buildings. Over the past decade, green building is increasingly the focus of attention among environmental economists and policymakers. There is no single definition of “green buildings” or its related policy. However, researchers and organizations tend to discuss green buildings in terms of impacts on human health, the environment, and resource use. A growing number of building policies in the United States and in other countries aim to mitigate these impacts.

Green building policies include voluntary programs and mandatory regulations, and vary to address concerns related to the entire life of the building, from design and construction to operation and deconstruction. These include component-level policies to promote energy efficiency, such as appliance standards, building codes, and other technology-specific regulations. Other policies are more general, addressing concerns indirectly related to the built environment: wetlands offset policies, antisprawl policies, and others fall in this arena. Throughout this dissertation, I focus on whole-building investments, rather than programs targeting only a single building characteristic (such as energy-efficiency). This preserves the importance of the myriad types of environmental impacts that can be addressed in the built environment.

In the next section I provide additional background concerning the green building movement. To emphasize the justifications for policy intervention in the built environment, I then review market failures and barriers that have given rise to green building programs. I discuss empirical evidence on the impacts of green building policies to demonstrate the viability of green building programs as a market solution, based on signaling theory. Then, I reflect on a key challenge that comes with the complexity of this policy approach: because of the immense flexibility of the green certification studied, certification pathways are not homogenous, creating noisy signals of building quality which would seem to undermine the policy's fundamental mechanism. To resolve this issue, and to advance a theory of noisy signals, I turn to literature on organizations and management. This provides the essential background necessary to engage more deeply throughout the dissertation, as I note in an overview of each chapter.

1.1 The Green Building Movement

The green building movement is a network of governmental, nongovernmental, and private actors seeking to address the environmental and human health impact of the entire life of a building, from construction to deconstruction. Green building techniques and practices have become increasingly popular even absent regulation. Voluntary building certification programs reduce the costs of acquiring information about a building and, by using a third-party certifier, credibly verify the environmental performance of a building. There are two related economic rationales for green building and related policies: to encourage firms to internalize externalities (Kingsley 2008) and to encourage the private provision of a public good (Kotchen 2006). A key strategy of voluntary building certification programs like the United States Green Building Council's (USGBC) Leadership in Energy and Environmental Design (LEED) is to tie a set of private benefits to public good production by program participants. That is, by building green, a developer averts environmental damage; by certifying green and joining the "club," a building owner signals quality to stakeholders (such as tenants and customers) to obtain a premium for his product (Potoski and Prakash 2009). Organizations may be able to capture economic value by certifying hard-to-observe process improvements.

Rather than stipulating specific standards or technologies, green building certification programs allow for the adoption of customized solutions for individual buildings. This flexibility is a critical characteristic that will premise much of the analysis contained in the dissertation. Certification programs like LEED incentivize an array of improved building technologies and construction practices, including those that improve outcomes in terms of energy, atmosphere, water use, water quality, materials use, as well as other categories. Owners certify a property by fulfilling criteria across a sufficient range of environmental outcomes, achieving one of the tiered certifications that signal an improved building quality. However, certification programs rarely disclose specific building improvements. This flexibility means that the evaluative criteria for green building spans multiple categories of environmental and human health impacts. This has hindered assessment of program effectiveness, and obfuscates common understanding of the certification.

1.2 Market Motivations and Market Failures in Green Buildings

Greener buildings perform better and can provide marketing benefits, though market failures inhibit adoption of many sustainable practices. The popularity of green building programs appears market motivated, rather than government-mandated: these policies and programs address market failures, such as asymmetric information and negative externalities.

Numerous performance advantages of green buildings arise from sustainable, efficient building operations. Kats (2003), Singh et al. (2010), and Turban and Greening (1996) are among those showing that enhanced building performance can come from energy efficiency, water efficiency, higher-quality outputs, and improved employee productivity (by helping to recruit and retain higher quality employees). Operational cost reductions and improved productivity enhance a property's value in resale or rental markets, and a variety of studies note how green buildings appear more resilient to climate, weather, regulatory, market shocks (Matisoff, Noonan, and Flowers 2016).

As a marketing opportunity, green certification operates as a signal to a variety of stakeholders. Green marketing may benefit green building owners by allowing the owner to derive economic value from the producing of positive externalities that appeal to environmentally-minded stakeholders. Green certification may improve firm reputation, and increase demand for products, such that the firm may capture market rents and premiums. Because certification requires above-code practices, adoption may also curry favor with regulators (Coglianese 2001). For example, Deng, Li, and Quigley (2012) show that certification to Singapore's Green Mark standard paid off following the strengthening of environmental regulations.

Despite demonstrated benefits of building green, market failures cause systematic under-production of sustainable buildings. These market failures include information asymmetries and externalities. By addressing these, the green building movement is an effort to better align the private costs of an industry with their social costs (Kotchen 2006, Potoski and Prakash 2009). A building label or certification signals stakeholders by verifying unobservable qualities related to mitigation of externalities.

1.2.1 Externalities

The built environment generates significant pollution, as the building life cycle has many unpriced externalities related to building construction, operation, and deconstruction. For example, waste from the construction process impacts air and water quality. Building operation produces unpriced air and water quality programs, social burdens related to energy use. Passively, a built structure also impacts water quality through storm water runoff. Site selection and site remediation affect urban development patterns and thus, indirectly, congestion, air quality, and other urban problems.

The green building movement seeks to reduce negative externalities in the building life cycle. Participants in voluntary green building programs such as LEED undertake costly private actions to produce public goods (by, for example, using sustainably sourced building construction materials). Yet owners face little incentive to mitigate externalities without some type of market intervention. To encourage participation, the stakeholders in the green building movement must also address information asymmetries.

1.2.2 Information asymmetries

There are often information asymmetries associated with green buildings, leading to the under-provision of difficult-to-observe building attributes. Builders have a better understanding of the construction process than building owners, and building owners or occupants have a better understanding of its design and performance features than potential buyers or tenants. For example, efficiency and indoor air quality are difficult to detect and verify prior to purchase or lease. This makes buildings akin to an experiential good, whereby the quality of the product cannot be observed until after consumption. This means that building owners may not have good information about the future value or operating costs of a greener building (Patel and Chugan 2013). Furthermore, some green qualities, such as sustainable material sourcing, construction waste diversion, are impossible to observe even after occupation. In this sense, green buildings are credence goods.

Difficulties detecting information about building quality can lead to a “market for lemons” in green building construction (Akerlof 1970), whereby low-quality (traditional) buildings crowd out the high-quality (green) buildings. This deters investment in green buildings. Certification signals such difficult-to-observe improvements to building performance (Mason 2012) and its overall footprint, which might include energy efficiency, indoor air quality, or construction processes. Once certified, builders can easily relate quality information to key stakeholders who prefer green qualities. These may include building buyers, tenants, and employees (Singh et al. 2010) as well as the owning firm’s customers and investors (Chegut, Eichholtz, and Kok 2011, Kahn, Kok, and Quigley 2013). Certification programs like LEED enable those who make the investments in green buildings to enjoy market premiums and recoup their expenses, through higher rental or sale prices for the property, or possibly lower wages for employees, greater availability of financial capital, higher prices for outputs, etc.

Signaling is effective when it reliable distinguishes green buildings from traditional ones. That is, to induce an equilibrium that confers premiums only to higher quality buildings, a certified product must be of demonstrably higher value to consumers. And, the information signaled must be understood with lower costs compared to obtaining full information. For specific building qualities (e.g., installation of certain technologies, use of renewable fuels), certification schemes can verify these improvements and distinguish high-quality from low-quality buildings. For the many qualities that might be signaled by green building certification (e.g., quality of management, firm's environmental commitment), less able or less committed owners will find it more costly to successfully adopt a certifiable green building (Mason 2012).

1.3 Evidence on the Economics of Green Buildings

As a signaling tool, empirical evidence suggests that green building certification is effective in establishing a separating equilibrium between high and low quality buildings. Several studies demonstrate financial benefits for building green. For example, Eichholtz, Kok, and Yonder (2012) find that real estate investment trusts (REITs) that have a larger percentage of LEED certified properties in the portfolio have a higher value and lower price volatility than REITs with a lower percentage of LEED certified properties. Chegut, Eichholtz, and Kok (2014) show that buildings in the United Kingdom that are certified according to the BRE Environmental Assessment Method rent for longer contracts and at a 28 percent rental premium. They also find that green certification provides a higher premium for rental properties than for properties that are for sale, highlighting the role of certification in reducing information asymmetries and providing a low-cost way for prospective tenants to judge the overall quality of a property.

1.4 Are Green Buildings Actually Greener?

Because green building certification allows for flexibility and does not entail specific technological requirements, and because each type of green building or energy efficiency label is unique, some authors have referred to green certification as a "noisy" signal of building quality (Fuerst and McAllister 2011c, Kok, McGraw, and Quigley 2011, Jaffee, Stanton, and Wallace 2012). Often the certification tier itself, rather than the building's raw score or specific improvements, serves as a market signal. In fact, Fuerst and McAllister (2011b), Deng and Wu (2013), Reichardt (2014a), and Shewmake and Viscusi (2014) note significant premium effects at each tier.

Historically, green building certifications have been far more about initial quality at the time of completion than about evaluating ongoing building performance. This adds to the noise in certifying performance. Recent LEED criteria and other municipal benchmarking efforts have attempted to address this disconnect between building design and performance by mandating energy efficiency requirements, requiring the use of energy monitoring, and using other behavioral nudges to encourage building users to optimize building performance (Palmer and Walls 2015). There is limited evidence suggesting that, on average, certified buildings cost less to operate than similar but uncertified buildings (Kats 2003). Energy efficiency would appear to be a promising area for operational cost savings and central to policy efforts aimed at promoting cost-effective green building upgrades (Chegut, Eichholtz, and Kok 2011).

The ambiguity of certifications that distill the many dimensions of green buildings into a single numeric score or tiered levels raises questions about the value of these certifications to the market. The fact that consumers appear to value the building's raw certification score over its tier (Kahn, Kok, and Quigley 2013) suggests there is a demand for information in the face of information asymmetries. Conversely, that LEED buildings tend to score just enough points to achieve the next certification tier suggests that the supply side of the market clearly recognizes the lumpy demand for environmental cachet and the symbolic value of green signals (Matisoff, Noonan, and Mazzolini 2014).

Despite increasing awareness of green buildings, the success of green building policy tools is unclear. Because of the flexibility in certification schemes, adoption is not homogenous, and the resulting noisy signals present challenges to measuring outcomes. Signal noise can be exploited by low-quality firms to reestablish a pooling equilibrium in which premiums for green practices deteriorate (Akerlof 1970). Yet, such pooling is not evident from the persistent economic returns to green certification. Can flexible programs produce tailored adoption for finely-tuned signals, or simply signal noise? The answer to this question motivates much of the research presented in this dissertation.

If signals are noisy, they are understood as less effective in traditional economic thinking. Much of the literature on green building (as an information-based policy, or as a strategic management technique) recognizes the value of certifications as a market signal (King and Toffel 2009), and recognizes heterogeneity in the practice of building green (Matisoff, Noonan, and Flowers 2016), but fails to account for the apparent contradiction between the signaling mechanism and the noisy signal. But, if it is possible that green signals operate in more than a binary fashion, what has been treated as signal noise may rather be a finely-tuned signal. To reconsider this noise as tuning requires revisiting the literature construct a nuanced view of green signals.

A broad body of literature has addressed voluntary programs, certifications, and green business extensively, but often treats all adopters homogenously. In doing so, large-scale inquiries can be conducted to identify either the motivations for sustainable behavior, or outcomes of adopting sustainable practices. This approach fails to recognize the contradiction between the presumed signaling mechanism of homogenous adoption, and the known practice of tailored adaptation. Yet a body of literature on organizations describes how and why practices evolve as they diffuse. To construct a framework for understanding signals as a multidimensional, finely-tuned mechanism, I draw on recent insights from organizations and management, integrating with established economic perspectives on signaling for a better understanding of signals, and signaling strategy.

1.5 Adoption Versus Adaptation

The observation that practices are not uniformly adopted is hardly new. Diffusion studies have long described the spread of new technologies through the population (Strang and Soule 1998). More recently, scholars have noted a distinction in the implementation of practices. As diffusion occurs, organizations can adapt practices to their particular needs (Ansari, Fiss, and Zajac 2010). However, not all may choose to do so. The literature describing the choice to customize or conform (Westphal, Gulati, and Shortell 1997), has been associated with a decoupling of means and ends (Meyer and Rowan 1977) to suggest symbolic adoption among many organizations motivated by legitimacy or loss aversion rather than performance (Kennedy and Fiss 2009).

Though frequently applied in past work describing distinctions among early and late adopters of and environmental practice (e.g., Delmas and Montes-Sancho 2010, Toffel 2006), these scholars do not differentiate adoption from adaptation, and cannot address the tension between the signaling mechanism and tailored signals. As I demonstrate, throughout my dissertation, key propositions from this literature can be leveraged to assess how adaptation of green building certifications may provide strategically tuned signals without undermining the signaling mechanism by creating noise.

I embark on this investigation in Chapter 2 by first describing the phenomenon of green building certification in a descriptive, rather than theoretical, way. This may be of interest to practitioners, and provides a clear depiction of the phenomenon on which theory is constructed in the remaining chapters. I then synthesize a framework for understanding green signals in Chapter 3. This framework reconsiders the description of green certification practices, bridging relevant literatures to integrate theory and practice. By connecting literature on disclosure, clubs, signaling, and organizations to two key dimensions of practice adaptation, I provide a generalizable approach to understanding green signals in other arenas. Data from LEED certifications apply this framework and demonstrate its applicability as a predictive tool describing the adaptation of a practice to particular organizational priorities.

The final two chapters complete my investigation, assessing trends over time with respect to these two key signaling dimensions. Though the environmental impacts of voluntary program participation and green labels tend to diminish over time (Delmas and Montes-Sancho 2010, Toffel 2006), such programs were established to improve quality and mitigate environmental footprints. As the labels diffuse, and as participation increases, some have claimed that a "Race to the Top" is occurring. Others might assert that greenwashing explains much of the observed participation, or even that a "Race to the Bottom" is occurring. Chapter 4 reflects on the theoretical origins of the Race hypothesis, develops a perspective under which a voluntary certification could induce a Race, and examines evidence of a Race within LEED buildings.

In Chapter 5, I elaborate on this analysis by providing analysis of high-resolution data. This chapter disaggregates LEED scores into their constituent technologies. By opening this “black box,” it is possible to directly examine how practices evolve, and examine the extent to which adopters adhere to the original aim of the program. The concluding chapter reflects on the key findings of this dissertation, noting key advances in theory and methodologies before highlighting promising areas of next research.

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CHAPTER 2: FOR WHAT IT'S WORTH: EVALUATING REVEALED PREFERENCES FOR GREEN CERTIFICATION

In a novel assessment of green building certification pathways, we observe how organizations obtain Leadership in Energy and Environmental Design (LEED) certification. We use a regression discontinuity approach to identify practices used to upgrade certification tiers. This analysis reveals preferences for green certification strategies and, we argue, intimates the perceived value of green certification. We distinguish practices that potentially confer private gains through returns to efficiency and productivity investments, from practices that only provide public benefits. Data show that organizations strategically certify to avoid high cost resource use, appeal to key stakeholders, and communicate building and organization quality. Builders upgrading to the highest tiers are more likely to deploy practices with private gains. Results suggest a willingness to extend short time horizons associated with energy efficiency investments in exchange for marketing benefits. Our discussion notes the capacity for certifications to mitigate market barriers associated with the energy efficiency gap.

2.1 Introduction

Sustainably designed buildings have numerous qualities that are difficult for potential buyers and occupants to observe. Hidden building qualities potentially lead to a "market for lemons" (Akerlof 1970) in which consumers cannot distinguish green or high-quality buildings from traditional or low-quality ones. These information asymmetries combine with other market failures and barriers (including externalities, high discount rates, and short time horizons), discouraging investment in energy efficiency and green building overall. Policy interventions seek to mitigate this gap between efficient and actualized levels of investment in green building (Brown 2001). Policies have traditionally been limited to building codes or other regulations, though market- and information-based instruments like labels or certifications have become increasingly popular (Matisoff, Noonan, and Flowers 2016).

Green building certifications verify sustainable qualities, communicating this hidden information to stakeholders (Amacher, Koskela, and Ollikainen 2004, Eichholtz, Kok, and Quigley 2010a, Mason 2013, Reichardt 2014b). That is, by certifying a building with a green label, owners quickly provide information to potential investors, tenants, consumers, and employees. This “signaling” may reflect on both the building and it’s owner or occupant (Matisoff, Noonan, and Mazzolini 2014), communicating quality at apparently at low costs (Eichholtz, Kok, and Quigley 2010a). By clearly distinguishing high- from low-quality buildings, certifications provide signaling benefits such as higher rental or sales prices for the property, among others (Chegut, Eichholtz, and Kok 2011). Signaling benefits incentivize otherwise cost-prohibitive green practices (Mason 2012).

As a tool for promoting sustainability and as a mechanism for signaling hidden qualities, green building certifications have become of increasing interest to practitioners and scholars alike. A variety of research has noted a recent increase in buildings that are certified with green labels (Chegut, Eichholtz, and Kok 2011, 2014, Cidell 2009, Kahn and Vaughn 2009, Kok, McGraw, and Quigley 2011). In particular, the United States Green Building Council’s (USGBC) Leadership in Energy and Environmental Design (LEED) label has gained significant traction in the United States. There, LEED certification labels as much as five percent of the new commercial buildings, and 30 percent of the new commercial office space in the 30 largest metropolitan areas (Kok and Holtermans 2014b).

The LEED program works by certifying specific building improvements that reduce the environmental footprint of a building. LEED certification is based the sum of dozens of different green practices, for which firms earn “credit” towards a composite score. LEED scores are then tiered into four certification levels. Some of these credits are thought to reduce a building’s operating costs by increasing efficiency, or are thought to improve employee productivity and improving indoor environmental quality. Other practices accepted toward LEED certification offer no such return on investment, but improve environmental outcomes for the surrounding community. Sustainable practices that offer no returns may be worthwhile if certification is leveraged to provide stakeholders some indication that the organization occupying the building is of elite quality, has green values, and is socially responsible (Potoski and Prakash 2009). Throughout, we refer to credits conferring potential returns as having private (versus public) benefits.

Flexibility of certification pathways, a feature common to many green building certification programs, introduces variance in the environmental practices used to certify buildings. This presents unique challenges to scholarly understanding of certification strategies in the built environment. What are organizations willing to do to gain signaling benefits? There has been much debate about the value of green certification, with unclear evidence on price premiums and energy intensity (Chegut, Eichholtz, and Kok 2014, Cidell 2009, Kahn and Vaughn 2009, Kok, McGraw, and Quigley 2011). A better understanding of certification pathway heterogeneity may shed light on the nuanced relationships between certification, market premiums, and energy efficiency. Analysis of certification pathways may indicate what builders hope to gain by going green, revealing latent preferences for green certification and signals.

Prior research has only identified broad patterns suggesting that certification can signal both building and organization quality (Matisoff, Noonan, and Mazzolini 2014, Corbett and Muthulingam 2007), treating certification behavior as a "black box" process. In contrast to other works that assess certification outcomes like energy intensity or sales premiums, we focus our analysis on the strategic decisions made to certify green in exchange for signaling benefits. We open the black box, using a proprietary dataset from the USGBC to examine building-level certification choices. Such high-resolution analysis has been limited to a handful of studies. Cidell and Beata (2009) aggregate buildings into large EPA regions, and sum credits by broad categories to explain regional differences in the use of general types of green practices. Others have used this data for small-*n* studies (Da Silva and Ruwanpura 2009) or have not sought to explain trends in certification pathways (Wu et al. 2016).

By opening the black box of green certification pathways, we contribute to a growing body of knowledge that seeks to understand strategic approaches to and motivations for environmental certification. In the following, we first introduce green certification and signaling, developing several hypotheses. Our methodology identifies practices chosen to carry a building from one tier of LEED certification to a higher tier, ascertaining signal value by examining changes in certification preferences at the margin. We demonstrate that organizations strategically adopt sustainability practices to avoid high cost resource use, appeal to key stakeholders, and leverage signals to communicate building and organizational quality. This evaluation fills gaps in scholarly understanding of green signaling strategy, practitioner perceptions of green label benefits, and policymaker's knowledge of outcomes under flexible program designs.

2.2 Literature Review: Green Certification Signals in the Built Environment

The built environment produces a wide array of externalities related to energy, water, air quality, and land use. And, many of these impacts are difficult (or impossible) to observe, inhibiting accurate valuation of improvements to building impacts. For instance, potential buyers cannot determine whether a building used sustainably harvested wood throughout construction at any point, and only ascertain whether the building design is energy efficient by assessing utility bills during occupancy. Many buyers and tenants are willing to pay more for greener buildings due to potential private benefits of reducing externalities, or simply because they value the public goods that green buildings provide (Brounen and Kok 2010). However, information asymmetries prevent them from offering this premium to builders who mitigate environmental externalities. These, and related market failures and barriers, have been shown to yield underinvestment in energy efficiency (Hirst and Brown 1990). Market failures likewise reduce incentive to provide public environmental amenities.

Certification serves as a signaling tool that rewards green building practices where numerous market failures deter sustainability. By certifying green, a builder credibly verifies improvements and provides a snapshot of overall quality for potential consumers (Matisoff, Noonan, and Mazzolini 2014). Green certifications signal potential buyers and tenants that a building, and its owner, are of high quality. Certification thus lowers information asymmetry about environmental externalities, often resulting in rental or sales premiums that incentivize green building (Reichardt 2014b). By attaching a premium to sustainable practices, certification mechanisms bundle private incentives to the provision of public goods (Kotchen 2013) and reduction of externalities. In the following, we provide a brief introduction to certification as a signal of building quality, and of organization quality. Our hypotheses build on this literature to suggest strategic signaling choices.

LEED is typically depicted as a quality or performance signal related to the building itself: by building green, owners gain a market return from efficiency and decreased production costs (Eichholtz, Kok, and Quigley 2010b). LEED buildings have been observed to consume nearly 30% less electricity compared to real estate establishments matched on a wide array of covariates (Asensio and Delmas 2017).[1] Other performance advantages associated with different LEED credits include, for example, indoor environmental quality that makes the building a more desirable place to work and increases worker productivity (Cole 1998, Cidell and Beata 2009). These private benefits to sustainable practices accrue even without certification, though, perhaps not surprisingly, rental and sales premiums tend to increase with certification (Eichholtz, Kok, and Quigley 2010b). While designers could reap benefits from green building without certification, information barriers may limit market returns to efficiency (Jaffe and Stavins 1994, Sallee 2014). Labeling through LEED allows owners to reduce information asymmetry between producers and stakeholders by verifying improved building performance with a simplified

[1] Other estimates have found smaller effects on energy efficiency (Kats 2003), and a rebound effect has also been noted: Newsham, Mancini and Birt (2003) observe greater energy use in about a third of commercial LEED buildings compared to general U.S. commercial buildings, though others found this above-average use in less than a quarter of LEED buildings (Turner & Frankel 2008).

signal of building quality (Mason 2013, Majumdar and Zhang 2009, Fuerst and McAllister 2011a).

Besides signaling performance qualities of buildings, LEED certification also indicates qualities of the owner organization, signaling quality management, strong owner values, positive environmental externalities, and even product quality. LEED as a signal of management quality and owner values has been observed through occupants' abilities to attract higher quality employees (Eichholtz, Kok, and Quigley 2010a). Further, Lanfranchi and Pekovic (2014) find that employees working for firms with green certification feel more useful and equitably recognized, and are more likely to work uncompensated overtime. LEED's signal of environmental quality may be important for investors (Saha and Darnton 2005), consumers (Sen and Bhattacharya 2001), employees (Turban and Greening 1996), or other stakeholders (Wood 1991). This is consistent with the theory that demonstration of corporate social responsibility (CSR) to stakeholders is linked to increased economic performance (Amacher, Koskela, and Ollikainen 2004, Lyon and Maxwell 2008), as perceptions of facility quality impact the owner, and the owner's goods and services. When LEED certification can be leveraged to signal organization quality, additional investments in sustainable practices may become worthwhile, whether those practices have tangible private benefits or not (Devine and Kok 2015).

In the context of LEED, building quality increases with each additional point obtained toward certification. However, the tiered certification structure means that *signals* of building and organizational quality only change as builders move from one certification level to the next. While building quality improvements often provide returns with or without signaling, organizational quality must be labeled to provide returns. This distinction is critical to the development of our hypotheses in the next section. Which practices are worthwhile at the margin between one level of signaling and the next, if potential signaling benefits drive owners to higher certification levels?

2.3 Hypotheses: Expected Signaling Strategies

The LEED certification program verifies building improvements in dozens of categories, corresponding to many types of environmental impacts across an immense set of available certification pathways. To give structure to the analysis of strategic certification, without losing the high resolution of credit-level data, we focus analysis on two dimensions. First, we examine the extent to which builders leverage credits with potential private benefits. Second, we examine strategies used to upgrade to higher LEED tiers, to send stronger signals of building or organizational quality. This approach opens the black box of green certification while reflecting on broader themes of interest to researchers and program managers. Our hypotheses test expectations that organizations strategically certify to (1) avoid high resource costs, (2) appeal to key stakeholders, and (3) signal that the building or owner is of high quality.

2.3.1 LEED as Cost Avoidance

All LEED credits mitigate externalities in some fashion, though some also provide private benefits. We distinguish between LEED credits that potentially confer private returns, versus credits that only benefit the broader public. Credits may confer private benefits by reducing operating costs or improving occupant productivity. For example, energy efficiency reduces utility bills to cut costs in the long run. On the other hand, habitat protection strategies offer no such return to the building owner. Practices that do not provide inherent returns are only worthwhile when bundled to private signaling benefits through certification. We provide a complete delineation of LEED credits in terms of potential return in the description of our data.

Notably, some in the buildings industry assert that there are no returns to the individual practices that constitute LEED certification. Because potential returns are small compared to upfront costs, and because returns are delivered over a long time-horizon, these building owners may discount potential returns to the point of negation. The emphasis on short time horizons and the use of high discount rates has been identified as a key contributor to the energy efficiency gap (Hirst and Brown 1990). From this perspective, the only gains of certification come from market premiums.

Our hypothesis, in contrast, is that LEED construction is leveraged to avoid high resource costs. Private benefits of efficiency increase when prices are high. If greater efficiency is implemented in locations associated with higher energy or water prices, we take this as evidence that certification is strategically leveraged to avoid high resource costs. If this hypothesis is upheld, returns to efficiency practices recognized by LEED must exist. Note that our expectation is consistent with past observations that adoption of efficiency practices increases when average prices are high for energy (Ito 2014) and water (Arrow 1966). While electricity rates vary by state and utility provider, water prices tend to be higher in urban areas with higher stormwater and wastewater management costs (Roy et al. 2003).

H1a: Energy efficiency credits are more popular in states with high electricity prices.

H1b: Water efficiency credits are more popular in urban areas with high water prices.

2.3.2 Customization for Stakeholder Appeal

As introduced above, organizations face many motivations for certifying LEED, and may do so to cater to numerous types of stakeholders. LEED's flexibility enables participating builders to customize certification pathways, choosing credits that produce outcomes desired by those stakeholders. Certification then verifies that a building has high quality (Spence 1973), and that the producing organization is of elite status (Potoski and Prakash 2009). Yet because LEED is typically studied as a black box process, we do not know the extent to which organizations customize certification pathways. While some argue that participants simply follow a pathway that reaches certification at least upfront cost, we expect organizations to leverage certification to signal key stakeholder groups interested in various performance qualities.

LEED buildings serve many functions**,** which have variable design needs, and provide services to diverse consumers. For example, a LEED certified apartment building may be more desirable to prospective tenants if the design emphasizes efficiency and indoor environmental quality. Hospitals and hotels may use similar strategies in appealing to their patients and guests. By contrast, government agencies may want to signal community stakeholders, emphasizing public goods rather than private gains. Our hypotheses illustrate the notion that certification is used to appeal to some core group of stakeholders, which demand either private or public benefits. Other hypothesis testing is possible based on available data; we test a litany of predictions derived from the same logic, and present the highlights in the results and discussion.

H2a: Residential buildings obtain more credits with private benefits for tenants.

H2b: Government buildings obtain more credits that have purely public benefits.

2.3.3 Signaling through Strategic Upgrades

Those willing to invest additional resources to reach a higher tier can reap marketing benefits by signaling greater performance (Matisoff, Noonan, and Mazzolini 2014, Corbett and Muthulingam 2007). Stakeholders may be more willing to pay, work for, or invest in organizations that can demonstrate green practices as part of a broader set of CSR initiatives (Saha and Darnton 2005, Sen and Bhattacharya 2001, Turban and Greening 1996, Wood 1991). Though two buildings may have nearly-identical environmental footprints, one may obtain an extra credit, upgrading to a higher certification tier, and signaling far greener than its peer. To gain the benefits of green signaling, many are induced to make additional improvements, obtaining just enough credits to upgrade to a higher level of LEED (Matisoff, Noonan, and Mazzolini 2014).

Past work by Matisoff et al. (2014) demonstrates that certain ownership types are more likely to participate in this upgrading for signal benefits. Those making upgrades for signaling are henceforth termed "signalers." We here assert that systematic differences should also exist in sustainable practices chosen between signalers and non-signalers. The probability of obtaining any particular LEED credit increases continuously and monotonically with the number of credits obtained. Likewise, the environmental impact, general building quality, and owner quality may increase continuous with each marginal LEED point. However, the signal sent by certification is discontinuous, increasing only as a project moves up a tier in the certification system. Identifying marginal credits chosen to carry a firm to a higher certification tier can demonstrate how organizations value green signals. Put differently, differences in credit attainment between signalers and non-signalers reveal what the signal is worth, by identifying which sustainable practices organizations are willing to adopt in exchange for signaling benefits.

Which sustainable practices are organizations willing to adopt for signaling benefits, which they are otherwise reluctant to pursue? We assume that a profit-maximizing firm adopts only practices deemed cost effective through private returns or signaling benefits. This allows us to draw on marginal differences in LEED credit adoption across certification thresholds to better understand the value green signals. Signalers may strategically select marginal credits that provide private returns, or may find other certification pathways to be more cost effective. Credits that do not yield returns ordinarily may be bundled to green signals that indicate high firm and product quality to become cost effective. By providing exclusive status in exchange for public good provision (Potoski and Prakash 2005b), credits providing only public benefits become more attractive components of certification pathways. Organizations facing greater quality competition, such as for-profit firms, may be more likely to pursue these signaling benefits (Matisoff, Noonan, and Mazzolini 2014).

H3: Credits providing only public benefits are more common among "signalers."

Recall that numerous market failures drive the need for green building policies like certification programs. As such, programs like LEED have multiple goals. Because some green practices cannot provide a return on investment, certification programs seek to provide private benefits for addressing public concerns. If signalers upgrade through credits with no private benefits, certification is an effective tool for addressing this market failure. However, certifications also incentivize greater energy efficiency in the face of short time-horizons and high discount rates that correspond to the energy efficiency gap (Hirst and Brown 1990). If the marginal efficiency measures are especially high cost, these mitigation practices have returns that only emerge over a much longer time horizon. Firms may not wish to adopt higher cost efficiency measures unless they certify at a higher level, because they are averse to these long-term investments with relatively low returns (Gillingham, Newell, and Palmer 2009). For the program to meet this goal, some signaling benefits must be associated with efficiency credits that provide modest returns. If so, we anticipate some signalers to upgrade through efficiency measures.

H4: Credits with low or long-run returns are more common among "signalers."

The expectations in Hypotheses 3 and 4 are only partially opposed to one another. There may be some organization types that become signalers through different strategies. Or, some certification thresholds may justify different types of investment. We explore this further in our analysis, results, and discussion. In the next section, we describe our data, which is uniquely situated to answer the questions presented. Then, we develop a methodology for identifying the marginal credit obtained toward certification before testing hypotheses.

2.4 Data and Methodology

The USGBC Green Building Information Gateway for the LEED New Construction version 2.2 certification program is the primary source of data for this study. Though data for other versions of LEED could be used, we restrict analysis to a single version for consistent comparison among green building pathways selected by designers. This version of the LEED standards allows a building to achieve up to 69 total points, with thresholds at 26, 33, 39, and 52 points representing the Certified, Silver, Gold, and Platinum tiers of certification, respectively. These thresholds correspond to 40%, 50%, 60%, and 80% of available "base" points (which exclude innovation credits), rather than to natural cut-points in sustainable design. Under this system, builders must strategically pick and choose sustainable design practices until the desired certification level is reached.

Data include all information for nearly three thousand LEED certified buildings, including categorical information on building owner, use, location, size, and whether the project was publicly or confidentially certified. We pair each LEED observation with local average electricity price data from the Energy Information Administration. This allows tests for a relationship between energy prices and the adoption of energy efficiency LEED credits. Water prices, typically higher in urban areas, are proxied with an ordinal measure of development density provided by the USGBC. This measure ranges on a seven-point scale from very rural to large metropolitan area. Data also include building scorecards, reporting precisely which of the 69 possible LEED points were attained as part of certification. Some of these credits correspond to private returns from efficiency or productivity improvements; others do not.

2.4.1 Classifying LEED Credits

We first assess differences in certification strategies that increase efficiency or productivity, netting private returns even without signaling benefits. When it could be argued that a LEED credit improves efficient use of natural or human resources, the credit is classified as producing private benefits. Using this logic, two types of credits exist by which LEED credits may provide such returns: *cost-saving* credits related to efficiency that decrease energy or water utility bills, and *user experience* credits related to indoor environmental improvements that enhance occupant productivity. The complete delineation of each LEED credit type is summarized in Table 1.

Table 2.1. LEED Credit Categorization by forms of returns. The number of points available for each credit is included to the right.

Private Returns: Cost-saving		**Private Returns: User Experience**		**Purely Public Returns**	
Optimize energy performance	10	Air delivery monitoring	1	Refrigerant management	1
On-Site renewable energy	3	Increased ventilation	1	Green power purchasing	1
Enhanced commissioning	1	Low-emitting materials	4	Construction air quality	2
Measurement & verification	1	Thermal comfort	2	Indoor chemicals	1
Controllability of systems	2	Daylight and views	2	Construction waste	2
Innovation and design	4	Development density	1	Renewable materials	1
LEED AP	1	Alternative transit	4	Certified wood	1
Building reuse	3			Site selection	1
Materials reuse	3			Brownfield	1
Regional materials	2			Habitat protection	2
Water-efficient landscape	2			Stormwater design	2
Wastewater technologies	1			Non-roof heat island	1
Water use reduction	2				
Rooftop heat island	1				
Light pollution reduction	1				

Cost-saving credits are identified in several forms. First, they may provide private returns by lowering electric utility costs through envelop efficiency, commissioned energy planning, and on-site renewable production. Second, efficient landscaping, low-flow internal water use, and innovative wastewater technology may similarly reduce water bills. Third, some credits lower costs in less obvious ways. Innovation and design credits frequently represent additional efficiency efforts in our data; reuse of materials during renovations avoid purchasing costs; reduction of rooftop heat island effects lowers the cooling cost of the building; reduction of light pollution limits wasted power for lighting;

and indoor system controls for lighting and temperature provide comfortable conditions with minimal intervention.

User experience credits, on the other hand, enhance productivity by improving indoor environmental conditions. Green buildings emphasize indoor air quality through low emitting materials and improved ventilation. High quality interiors may also provide thermal comfort and controls, views of the outdoors, and lighting improvements. Neighborhood characteristics including development density, walkability, and access to alternative transit may also be preferred by users. Credits in this category are thought to reduce employee absences, attract better quality employees, enhance retention, and improve employee productivity (Turban and Greening 1996, Lanfranchi and Pekovic 2014). Though not every credit listed in the cost-saving or user experience category yields a return for every building, we distinguish credits by their *potential* to provide a return.

2.4.2 Descriptive Statistics

Table 2 displays descriptive statistics of the data, focusing on distributions of obtained credits which potentially provide private benefits. For various owner and use categories of LEED buildings, the table shows mean LEED score and mean percent of score from credits that associated with private benefits (*%Private*). Statistically significant differences in subsample and population means are indicated. Notably, homes and hotels appear to attain above-average credits conferring private returns. Schools, hospitals, government facilities, and confidentially certified projects score below-average in terms of credits with private returns. Large buildings also appear less likely to attain private return credits.

Table 2.2. Means of LEED Project Points and percent of score from credits with private returns, with tests for significant differences of subsample means compared to the overall sample.

(Sub) Sample	*N*	*LEED Score*	*%Private*
All	2981	38.36	68.76
Government	1694	38.67***	68.56**
For-Profit	554	37.21***	69.11
Nonprofit	496	38.82*	68.98
Other Owner	237	37.91	68.98
Confidential	581	37.44***	68.19***
Signaler	1432	37.16***	68.71
Civic	419	38.20	69.06
Commercial	653	38.96***	68.70
Education	653	38.77*	68.43*
Healthcare	164	36.54***	67.79**
Hospitality	66	36.75**	70.77**
Industrial	110	38.02	68.63
Residential	170	38.12	71.00***
Retail	108	35.75***	68.47

*, **, *** for p-value < 0.1, 0.05, 0.01, respectively.

We compare prices and the adoption of LEED credits with private returns, observed as the total number of credits attained, the number of credits attained in LEED's Energy and Atmosphere (EA) and Water Efficiency (WE) categories, the total credits obtained that confer private returns, the total credits obtained that only provide public benefits, and the share of credits obtained that confer private returns (*%Private*). Each of these variables is correlated to some extent with energy prices and urban density (a proxy for water prices). Correlation values and indications of statistically significant covariance are listed in Table 3. Investment in EA credits, which mostly confer private returns, is positively correlated with local electricity prices. Urban developments tend to have more EA and WE credits, but lower LEED scores overall.

Table 2.3. LEED Credits Correlations with building setting, including measures of resource costs.

	Electricity Price	Urban Density	Building Size
Energy & Atmosphere	0.083 ***	0.035*	-0.047 ***
Water Efficiency	-0.028	0.117***	-0.035 *
LEED Score	0.037 *	-0.077***	0.025
Credit Count: Private Returns	0.085 ***	-0.055***	0.020
%Private	0.125 ***	0.024	-0.044 **
No ROI	0.001	-0.096***	0.077 ***

*, **, *** for p-value < 0.1, 0.05, 0.01, respectively.

Table 2.4. Mean Credits earned by Various Owner Organizations and difference from population mean. T-statistics are listed in parentheses.

	Building Sector					
LEED Credit Category	**All**	**Gov.**	**Firm**	**School**	**Industry**	**Home**
Energy & Atmosphere	7.51	7.76	6.97	7.58	7.94	6.86
		(4.34)	(-3.98)	(0.53)	(1.28)	(-2.46)
Indoor Environment	9.92	10.03	9.40	10.25	8.65	9.64
		(3.19)	(-6.33)	(4.41)	(-6.33)	(-1.77)
Materials & Resources	5.55	5.61	5.45	5.59	5.68	5.08
		(2.13)	(-1.54)	(0.71)	(0.84)	(-3.84)
Innovation & Design	3.96	3.89	4.08	3.90	4.15	4.22
		(-3.90)	(3.01)	(-1.45)	(1.89)	(3.13)
Sustainable Site Selection	7.98	7.88	7.94	8.12	7.83	9.09
		(-2.90)	(-0.46)	(2.03)	(-0.77)	(7.24)
Water Efficiency	3.46	3.52	3.38	3.34	3.78	3.25
		(3.50)	(-2.23)	(-3.69)	(3.62)	(-3.08)
Private Returns	26.68	26.73	26.18	26.81	26.37	28.09
		(0.66)	(-2.35)	(0.76)	(-0.64)	(3.34)
User Experience	10.00	9.92	9.81	10.26	9.04	10.55
		(-2.42)	(-2.45)	(3.78)	(-5.08)	(3.69)
Cost Saving	16.64	16.78	16.35	16.49	17.29	17.40
		(2.06)	(-1.64)	(-1.00)	(1.63)	(2.16)
Number of Buildings (N)	2981	1694	554	653	110	170

We test whether certification pathways are customized to building types with respect to each credit category. With so many credits on the LEED scorecard, this process demands hundreds of *t*-tests to reveal statistically significant differences in pathway strategy. A few of the highlights of these tests are reported in Table 4, which compares subsample means to the full population. This table focuses on our interest in credit attainment patterns among residences, government facilities, and other groups within the data, such as confidentially certified buildings.

2.4.3 Patterns in Organizational Performance Signaling

To assess strategic signaling decisions, we narrow analysis to the thresholds between LEED certification levels. We observe differences in signalers, compared to those who do not upgrade, by employing a regression discontinuity test from Porter (2003). The dependent variable in this analysis is the probability of obtaining individual credits, or the propensity to obtain credits within certain groups. This approach reveals preferences for green certification by indicating the marginal green practices pursued for signaling purposes. By assuming that, on average, builders obtain LEED credits until the marginal utility of the credit equals the marginal cost of the credit, we can observe the additional value from signaling at a higher tier as related to jumps in credit attainment at thresholds. That is, we assume that owner investments in green practices amount to what a green signal is worth to the owner. Because building quality and environmental impacts change only modestly with each additional credit, significant jumps in propensity to attain a credit at a threshold reveal preferences for signaling. We are also able to assess related trends based on building owner type, building use, and a few other project attributes.

The regression discontinuity test estimates separate local regressions from the left and from the right of a given treatment threshold. In the LEED setting, the treatment is the additional signaling, awarded at the point threshold between each certification tier (33 for Silver, 39 for Gold, or 52 for Platinum). By smoothing from the left-hand and right-hand sides of the threshold, this method produces two different expected values for the dependent variable at the certification threshold. The magnitude of the difference between the expected values, α, reveals whether a project attribute is more likely or less to be observed among signalers. When statistically significant, α reveals which practices are leveraged to obtain signaling benefits, though those credits were not revealed to be strategic at lower tiers. A positive α means that there is a disproportionately large increase in observations of its kind above the threshold. An α below zero would indicate a paucity of observations above the threshold. For example, an α of 0.23 would indicate that the probability of obtaining a LEED credit increases by 23 percentage points as a builder chooses to upgrade beyond the threshold under examination.

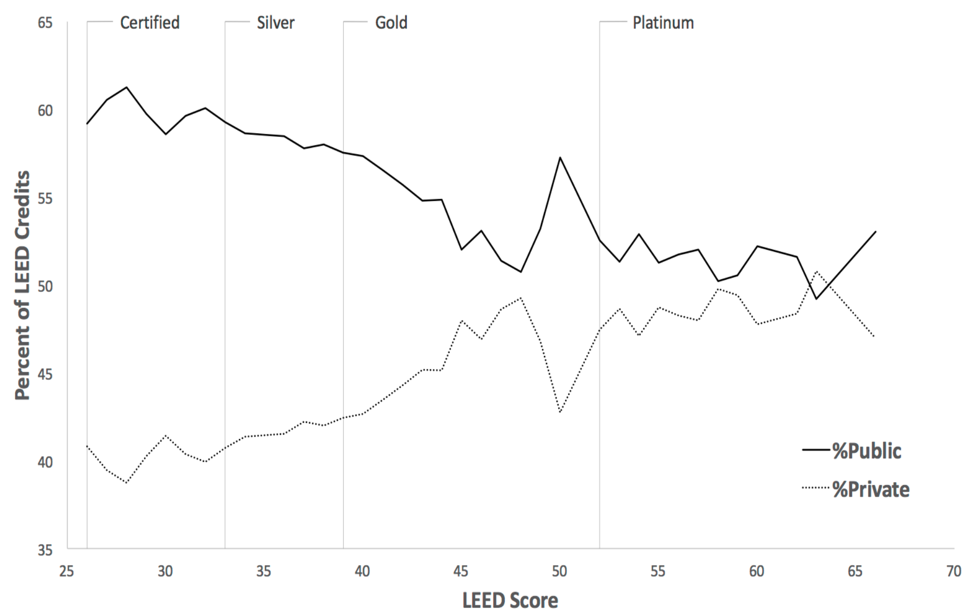

Figure 2.1. Achievement of LEED Points associated with potential private returns versus purely public benefits, as a percentage of total LEED score.

The Porter (2003) approach has several advantages. First, we can observe shifts in the distribution at each individual LEED threshold, for any project characteristic. Second, we can statistically identify discontinuities that may not be visually apparent. For example, in Figure 1, it is not clear whether the share of credits attained that have private benefits (*%Private*) changes at all as LEED scores change from Certified to Silver, Silver to Gold, or Gold to Platinum. However, significant differences may exist. Third, by smoothing from both sides of the threshold, we control for differences in density of observations above and below the threshold, and additionally control for the loss of degrees of freedom when choosing pathways to higher LEED scores.

Analysis requires assumptions about the appropriate bandwidth chosen for local smoothing. Results are somewhat sensitive to this choice: larger bandwidths include more data and often have more precise fits. However, in a multi-tier setting, increasing the bandwidth risks bias by including data from regions of the distribution influenced by adjacent thresholds. This bias might obscure localized discontinuities. To this end, we opt for a three-point bandwidth at the Silver and Gold tiers (33 and 39 points, respectively), the smallest bandwidth that reliably describes patterns in the multitier framework. For the Platinum threshold (52 points), which is farther from (and less influenced by trends related to) other thresholds, we increase the bandwidth to four points. This in part compensates for the absence of any observations scoring 51 points, just a single credit shy of the Platinum tier. Further (not reported here) sensitivity tests at other bandwidths for each credit indicate robust results.

2.5 Results

In the above descriptive statistics, we observe evidence that LEED is used to avoid high cost resource use, and appeal to key stakeholder groups, confirming our first two groups of hypotheses. In Table 3, we observe that building owners facing high electricity prices are more likely to draw on energy efficiency improvements and related LEED credits associated with a potential return. Owners certifying in more densely developed urban areas (where water prices tend to be higher), are more likely to adopt water efficiency technologies. Notably, there appears to be some indication that urban projects have lower LEED scores, obtaining fewer credits overall. That the results are negative and significant for credits with both private and purely public benefits, yet the result for *%Private* is insignificant, suggests that urban developments do not vary systematically from rural developments in terms of prioritization of returns. On the other hand, larger buildings appear to rely less heavily on private returns. This may suggest diseconomies of scale for some efficiency technologies. Because owners appear to respond to prices through efficiency, we take these results as an overall confirmation that private returns exist and are recognized for at least some of the LEED credits.

In Table 4, we observe small but statistically strong differences in LEED certification pathways across owners and building uses. For example, government projects score on average 0.25 higher than the general population mean LEED score (Table 2), yet they tend to achieve fewer credits for Innovation & Design and Sustainable Sites. They perform especially poorly in public transportation credits, and rarely attain building reuse and materials reuse credits. High LEED scores for government agencies rely on Energy and Atmosphere, Indoor Environmental Quality, Materials and Resources, and Water Efficiency credits. They tend to earn fewer *user experience* points and more *cost-savings* points.

Table 2.5. Regression Discontinuity Tests across LEED certification tiers. Note that α values were computed at bandwidth of 3 for thresholds at Silver and Gold; bandwidth of 4 was used for the Platinum threshold. Values for α correspond to the additional probability of obtaining a credit in order to obtain the listed certification tier, compared to observations just shy of the tier.

	α – Discontinuity Magnitude at Threshold		
Project attribute	**Silver**	**Gold**	**Platinum**
Private Returns	0.068	0.168	8.691 ***
%Private	0.003	0.004	0.174 ***
Purely Public Returns	0.160	-0.240	-4.125 ***
%Public	0.005	0.006	-0.083 ***
User Experience	-0.343	-0.124	0.393
Cost-savings	0.412	0.293	8.298 ***
Energy & Atmosphere	0.224	-0.398	7.417 ***
Indoor Environment	0.399 **	-0.501 ***	-2.112 ***
Materials & Resources	-0.812 ***	0.454 ***	0.688
Innovation & Design	0.242 *	0.180 *	1.597 ***
Sustainable Sites	-0.619 ***	0.304 *	-3.720 ***
Water Efficiency	0.662 ***	-0.004	-0.779 ***
Confidential	0.031	-0.066	-0.620 ***
Energy price	1.249 **	0.071	6.309 ***
Certification year	-0.140	-0.164 *	-1.463 ***
Government	-0.015	-0.051	-1.001 ***
For-Profit	-0.119 **	0.074 **	0.177 **
Nonprofit	0.140 ***	-0.017	0.754 ***
Other	-0.006	-0.007	0.069
Civic	0.127 **	-0.159 ***	-0.775 ***
Commercial	0.096 **	0.107 **	0.241 ***
Education	-0.052	-0.022	0.037
Healthcare	0.054 **	0.002	0.048
Hospitality	0.031 **	-0.002	0.019
Industrial	0.063 **	-0.042 **	0.024
Residential	-0.255 ***	0.022	0.283 ***
Retail	-0.043	-0.031	0.024

By comparison, firms appear to use the opposite strategy, scoring low where government buildings tend to score high, and vice-versa. Schools place most focus on indoor environments and user experience, affirming that school certification is used to improve student health and comfort. Industrial projects place very little emphasis on the indoor environment, but emphasize water efficiency. Residential buildings emphasize efficiency and user experience, though they have lower overall LEED scores compared to other buildings. Taken together, these results confirm our hypotheses by demonstrating certification pathway customization to key stakeholder interests.

On average, buildings do not exhaust opportunities for either private benefits or purely public benefits at any point total, as observed in Figure 1. Instead, they select a combination of building improvements, with a consistent extent of investment in credits that do and do not confer private returns across LEED scores. While Figure 1 does not clearly reveal major discontinuities on visual inspection, the Porter test offers a formal measure of this trend, and facilitates comparison between signalers and non-signalers, in terms of numerous project attributes. Results of these tests, including evidence of Hypotheses 3 and 4, are shown in Table 5.

Discontinuities in credit attainment patterns reveal signaling strategies. The data suggest that some credits are especially likely to increase in popularity when building owners upgrade to higher certification tiers. As coded, signalers' strategies do not appear to leverage credits with private benefits overall. However, some individual credits and credit categories do show statistically significant differences in adoption patterns as buildings cross a certification threshold. At the Silver level, signalers are more likely to select credits for Indoor Environmental Quality, Innovation & Design, and Water Efficiency. On the other hand, these buildings also tend to have significantly fewer Materials & Resources and Sustainable Sites credits, compared to those who do not upgrade from Certified. The low-tier signalers appear drawn to credits with purely public benefits (in support of Hypothesis 3), but appear to avoid materials and thermal comfort credits.

At the higher tiers, different patterns emerge. Gold signalers more frequently leverage Materials and Site Selection credits, but less often choose improvements to Indoor Environmental Quality, including thermal comfort credits. When projects upgrade to Platinum[2], the focus on Indoor Environmental Quality drops, and Green Power Purchasing credits become over 70% less likely. To reach the highest tier, owners switch signaling strategies, increasing energy efficiency from the Energy and Atmosphere credits far beyond what is adopted in LEED Gold buildings. In fact, Platinum signalers obtain on average eight more credits from the private benefits category compared to those obtained by LEED buildings certified at the higher reaches of the Gold tier. In addition to the other results from various credits and categories, this confirms the expectations from Hypothesis 4.

Threshold discontinuities can be observed along various other project attributes. Past work identified these tendencies for owner type (Matisoff, Noonan, and Mazzolini 2014), which we replicate somewhat. We also divide the sample by building type: commercial office buildings tend upgrade for signaling benefits at every level of certification, but civic buildings tend only to upgrade for Silver certification. Residential and industrial buildings are especially unlikely to be signalers. Education and retail facilities reveal no significant preferences for upgrading for signaling benefits.

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[2] At the highest certification tier, a paucity of observations on either side of the Platinum threshold limit interpretability of result magnitudes. The extension of the smoothing bandwidth to four credits partially adjusts for the small dataset, and significance is robust to a variety of specifications. Thus we interpret results at the platinum level, but with some caution.

2.6 Discussion

The data provide a glimpse into the revealed preferences for signaling, and our analysis provides unique insight into organizations' green certification strategies. Most research is only able to observe whether certification occurs, along with occasional metrics or environmental or financial performance. In contrast to some assertions that certification pathways are homogeneous or non-strategic, these results demonstrate that owners change building practices to minimize costs, signal key stakeholders, and accrue green signaling benefits. Lessons from this analysis have implications for builders seeking to strategically signal, policymakers designing programs to address market failures, and scholars researching green labels and signaling. We address each of these in turn.

Our data show that efficient design practices are more popular under high resource prices. This suggests that, even when upfront costs are high, returns on investment in energy and water efficiency are an important factor in an organization's decision to "go green." However, not all LEED credits increase efficiency or otherwise provide a return. LEED's flexibility fosters variance in certification pathways, some of which may provide higher or faster returns. This gives builders opportunities to strategically reach certification through customized pathways.

We observe that different types of buildings leverage certification differently, with no singularly "best route" to LEED certification. LEED certification pathway decisions appear influenced by the owning organization, its goals, and its stakeholders. Organizations can match how they certify to their underlying motivations for certification: schools can provide healthier environments for students, firms can differentiate themselves as innovators in a crowded industry, and home-owners can save on utilities, all within the same certification program. Such flexibility may be critical to encouraging widespread adoption among builders, but also creates highly variable environmental impacts from one LEED building to the next. Customization towards LEED certification has created “noisy” signals, variably indicating qualities to differentiated stakeholder groups, and potentially explaining some of the divergence in existing literature that aims to quantify environmental and marketing outcomes of LEED certification.

To illustrate this signal noise and its potential causes, take for example the difference in government and firm certification pathways. These owner types share few certification habits, potentially due to different procurement policies, or different views on what constitutes a viable return on investment. Differing managerial perspectives between the public and private sectors may drive the divergence in certification pathways, as public managers find ways to justify very different sustainability practices compared to firm decision makers. The popularity of innovation credits may be explained by where they pay off (in the for-profit sector) versus where they are difficult to justify (for government agencies). Firms may face shorter time-horizons or use higher discount rates compared to government agencies, due to the shareholders they must appease. Governments, on the other hand, may face more political pressures to make popular decisions. This may explain why governments are much less likely than firms to obtain Sustainable Site credits (if government groups site offices using political calculus to meet constituent needs, rather than heading best practices in urban planning or providing transit access for employees).

The regression discontinuity results may be particularly interesting to policy makers and scholars. We find distinct preferences for some practices as organizations upgrade to higher tiers of certification. This analysis may be understood as revealed preference for green signaling: the marginal credit organizations are willing to obtain to reach a threshold should be equal to the associated increase in signaling benefits. The results indicate what the signal is worth to various builders. Governments obtain high energy and water efficiency credits at all LEED scores, whereas firms draw on efficiency measures mostly to reach higher certification tiers. It appears that the signaling benefits of LEED certification may offset high discount rates for energy and water efficiency improvements (Sallee 2014, Jaffe and Stavins 1994, Gillingham, Newell, and Palmer 2009, Allcott and Greenstone 2012). By amplifying the visibility of building and organizational quality to key stakeholders, LEED certification expedites returns to enhanced efficiency, making even low-return and long-time horizon practices more attractive to organizations that would not ordinarily pursue them. Tiered information-based program designs similar to LEED certification may therefore prove useful in reducing the energy efficiency gap.

Signaling benefits do not incentivize all organizations equally. As Matisoff et al. (2014) demonstrated, some owner types are more willing than others to make upgrades in pursuit of green signaling. Our analysis finds that the types of practices used for upgrading signals also vary. Although upgrades to the highest certification tiers tend to come from energy efficiency, projects certifying at lower tiers are more willing to pursue credits that offer no potential private return. Preferred practices among Silver signalers mitigate environmental footprints and provide positive externalities for the community. Such public goods are not ordinarily provided by the private sector. This suggests that public good provision is also incentivized by bundling public goods to private investments through clear information signals, as in LEED certification.

By observing LEED certification pathways, we gain insight into the underlying motivations for green signaling, intimating the targets of green signals. Our methodology extends regression discontinuity approaches to reveal preferences that drive signaling behavior. Results suggest how organizations value signals by determining what they are willing to do to gain certification. Yet this method does not directly explain why signalers are more dependent on efficiency, but only at higher tiers. Nor is it clear why other credits (like indoor environmental quality) are less favored at higher tiers. These statistical tests reveal meaningful relationships that reflect the efficacy of certification programs to address market failures, but do not identify causal relationships. Careful identification of green signaling mechanisms is left to future inquiry.

Theoretical developments in learning, technology diffusion, and signaling will enhance scholarly understanding of complex policy approaches like LEED. First, the LEED credit selection process is not obvious, though explanations may arise from the study of networks, identifying learning and diffusion patterns within and across markets for green building. Second, the existence of confidentially certified green buildings, who are sustainable but cannot advertise their LEED status, is a perplexing observation that challenges assumptions about LEED as a signal. Future work may leverage confidentially certified buildings to clarify motivations for green practices and green signaling. Finally, from a signaling perspective, we note that LEED produces noisy signals, yet signaling theory suggests that only clear and homogenous signals are of value. This contrasts with LEED's rising popularity and notable market premiums. Can a nuanced theory of green signals help answer this discrepancy? More than just philosophical parley, the answers to these questions will aid practitioners in the design of policy programs and in the implementation of sustainable development initiatives.

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CHAPTER 3: CROWDING OUT OR TUNING IN? A FRAMEWORK FOR NOISY SIGNALS

The decision to certify green or voluntary participate in an environmental program is often considered a quality signal that can help gain marketing premiums. However, the economic theory on signaling is best suited for qualities that are unidimensional, rather than multifaceted or multidimensional characteristics like sustainability. Past work has considered the multidimensional nature of some qualities as "noise" that crowds out signals of quality. This chapter revisits the treatment of signal noise in an assessment of the quality improvements made toward green certification. An organizational perspective on signaling theory provides the foundations of a framework for noisy signals, which integrates existing literature on signaling, club theory, and information disclosure. This framework provides a way to assess differences in practice adaptation in two-dimensional space. That technologies selected toward certification are demonstrated to match organizations' stakeholder demands suggests that signals are fine-tuned to meet strategic aims.

3.1 Introduction

Labels of corporate sustainability and social responsibility are increasingly popular across markets (Darnall 2016). This trend has captured the attention of various threads of disciplinary and interdisciplinary research. As a matter of practice, many have studied the diffusion of the green technologies, the learning curves depicting adoption trends (Boss 1980, Cantono and Silverberg 2009), and the environmental performance of adopters (Koehler 2007). Through various theoretical lenses, many have studied the financial performance of adopters (Flammer 2013, 2015), the environmental performance of adopters (King and Toffel 2009), the motivations to adopt (Koehler 2007), and the governance of these programs themselves (Bernstein and Cashore 2007).

Despite this variety, most literature accept green labels as a type of signaling strategy firms enact to distinguish themselves as having higher quality (Darnall and Carmin 2005). In cases in which the true qualities of goods cannot be easily observed, a potential "market for lemons" exists that inhibits consumers' ability to ascertain high- and low-quality goods and services (Akerlof 1970). This induces a pooling equilibrium in which consumers pay the same, regardless of quality, leaving firms little incentive to improve hidden characteristics (Spence 1973). A key characteristic of quality signals is that the quality of the good is only perceived through user experience (Lee 2001). Direct benefits from some improvements to performance and quality can accrue to users, but returns may not be fully appropriated by producers without overcoming information asymmetry (Stiglitz 2000).

By introducing a quality label as a market signal, a separating equilibrium can be established to confer premiums to high-quality goods and services. These premiums may exist as higher price, increased market share, greater availability of financial capital, improved government relations, or even lower wages for employees who derive utility from working at a quality firm. Importantly, the signaling theory that Spence (1973) articulates hinges on consumers willing to pay for qualities they may benefit from directly.

In the case of environmental labels, this pertains to the numerous production and processing externalities related to the good's lifecycle, as well as potential public and common goods impacted by the firm's operations. Green labels denote qualities bundled to the good itself (Kotchen 2013). Because a precise definition of "sustainability" is elusive (Norton 2015) these labels have come to denote a wide array of characteristics. Labels vary in the extent to which they are self-reported versus externally certified, and vary by the number of characteristics they consider, among others (Ji and Darnall 2017). As a result, there are often multiple labels available for any particular product. For example, green buildings in the U.S. are labeled with Energy Star certification that benchmarks energy efficiency, Leadership in Energy and Environmental Design (LEED) certification that takes a holistic approach to verifying environmental footprint improvements, and a variety of other labels with similar approaches to LEED but with slightly different certification requirements.

As labels diffuse, their efficacy as a signaling strategy hinges on continued consumer recognition and understanding. That is, if consumers cannot determine what a label means, or if they cannot recall which among the many labels are meaningful, they will not accept the label as a signal of quality, and will not be more willing to pay for the suggestion of that quality. This reestablishes the pooling equilibrium as low-quality firms "crowd out" signals from veritable improvements (Akerlof 1970). So long as a separating equilibrium exists, rent-seeking firms face incentives to overstate their quality in order to gain access to premiums conferred by labelling (Stiglitz 2000). Such 'free-riding' has been termed greenwash (Lyon and Montgomery 2015), though numerous definitions of this term exist (Kim and Lyon 2015). Where product (environmental) quality is heterogeneous among labelled items, the resulting signal is considered "noisy," and consumers cannot accurately interpret value from the signals, undermining the effectiveness of the signal (Akerlof 1970).

Although this suggests that signals of green product quality ought to be homogenous to be effective, the qualities that make a product sustainable are immensely varied, and evolving (Norton 2015). Much work has examined the institutional design of labels, suggesting enforcement mechanisms that limit free-riding (Darnall, Potoski, and Prakash 2009) and governance mechanisms to improve legitimacy (Bernstein and Cashore 2007). But these do not address the heterogeneity of qualities within products that demonstrate sufficient sustainability for certification: often, labels and certification programs offer flexibility for firms seeking to improve many (not all) qualities (Potoski and Prakash 2009). As a result, signals may be less correlated with latent product quality (Karamanos 2003), as flexibility permits customization, as organizations "tune" their approaches to sustainability to their particular needs, goals, concerns, or stakeholder demands.

In the case of green buildings, heterogeneous product quality has at times cast doubts on the efficacy of the labeling systems. Some green certified buildings save tremendous amounts of energy when compared against a matched sample (Asensio and Delmas 2017). However, a rebound effect has been suggested, in which certified (or efficient) buildings in cases use far more power than their uncertified counterparts (Kats 2003). Yet this performance heterogeneity has not demonstrably undermined the value of green labels: premiums have been observed through enhanced rental and sales rates (Eichholtz, Kok, and Quigley 2010a), increased occupancy (Eichholtz, Kok, and Yonder 2012), and improved worker productivity and satisfaction (Singh et al. 2010). This contradiction, generally unaddressed in past research, justifies further consideration. Can noisy signals play valuable roles for firms seeking to reliably demonstrate quality to consumers? If so, how?

In the following, a framework for understanding noisy signals is synthesized from literature on practice adaptation. Key measures of adaptation, fidelity and extensiveness, are shown to be related to central discussions of corporate sustainability: environmental disclosure and green clubs. Linking these perspectives with traditional understanding of signaling, the following synthesizes a framework for understanding noisy signals of product quality. As an application, data on green building (LEED) certifications are assessed through the framework to demonstrate how organizations may tune signals to specific stakeholder interests, without crowding out signals from other certification pathways.

3.2 Practice Adoption and Adaptation

Traditional signaling perspectives assume signals as binary, either present or absent. In this sense, labels signal the homogeneous adoption of specific quality improvements. Past literature describes the probability of adopting a practice, or else describes the processes by which practices diffuse to new adopters (Ryan and Gross 1943, Rogers 1976). Recent work has pivoted from describing adoption, a process that implements existing technology in new places, to describing adaptation, a process that in which technologies evolve as they diffuse (Ansari, Fiss, and Zajac 2010).

This adaptation has been described in a variety of ways, throughout the literature on institutional sociology. Most often, this body of literature distinguishes between a practice as implemented among early adopters, and its implementation among late adopters. As Westphal, Gulati, and Shortell (1997) note in a study of Total Quality Management, early adopters are prone to tailoring the practice to fit particular needs, while late adopters are more likely to adopt some pre-established, dominant form of the practice. Customized approaches are often considered more substantive, in that they are more likely to accomplish the original aims of the program (Westphal, Gulati, and Shortell 1997). By contrast, adoption by conformity is often considered symbolic (Delmas and Montes-Sancho 2010), as the means of adoption become decoupled from the ends of adoption (DiMaggio and Powell 1983, Bromley and Powell 2012).

This phenomenon is explained by theory describing shifts in the motivations to adopt. Early adopters tailoring their approach are motivated by a sincere desire to achieve some goal set forth by the program, but late adopters may be influenced to adopt in response to a variety of social pressures, rather than technical opportunities (Kennedy and Fiss 2009, Tolbert and Zucker 1983). These social pressures arise as adoption becomes increasingly expected, either due to normative and mimetic processes or policy coercion (DiMaggio and Powell 1983). In response to coercion, organizations may adopt to-rule (Roy 1952) but avoid adoption at depth (Westphal, Gulati, and Shortell 1997). In response to other social pressures, organizations may adopt to gain legitimacy (Tolbert and Zucker 1983), or simply to avoid losses (Kennedy and Fiss 2009).

The manner in which practices evolve as they diffuse has been characterized as adaptation along two dimensions, either of which may change as practices evolve (Ansari, Fiss, and Zajac 2010). First, Ansari et al. (2010) describe *fidelity* as measuring how truly the adopted version of the practice reflects the intended scope and meaning. This construct, alternatively been termed *accuracy* (Yuan et al. 2005), is not intentionally normative, in that it does not reference an ideal cannon for adoption, but only distinctions compared to other adoption (Ansari, Fiss, and Zajac 2010). In this sense, a prototype for adoption by an early adopter is not the "ideal," but does provide a useful reference point for comparison (Lewis and Seibold 1993). Second, *extensiveness* is the extent to which a practice is implemented on adoption (Ansari, Fiss, and Zajac 2010). By some termed *intensity* (Wu, Mahajan, and Balasubramanian 2003) or *depth* (Corbett and Muthulingam 2007, Westphal, Gulati, and Shortell 1997) of adoption, this dimension characterizes how "far-reaching" the implementation effort becomes (Ansari, Fiss, and Zajac 2010).

These dimensions of practice adaptation have been depicted as orthogonal characteristics of a two-by-two matrix, with a variety of propositions noting conditions under which certain shifts may be expected (Ansari, Fiss, and Zajac 2010). By comparison, little of the literature assessing outcomes of voluntary programs, labelling, and certification acknowledges adaptation except as a limitation (Matisoff, Noonan, and Flowers 2016), and literature on signaling assumes practices do not evolve unless to undermine the signal (Stiglitz 2000). Yet, as shown in the following, the constructs presented in adaptation can be readily mapped to our understanding of signaling, disclosure, and clubs. In doing so, previously disjointed constructs are synthesized into two-space, for a framework for understanding noisy signals that draws heavily on theory of organizations.

3.3 Constructing A Framework for Noisy Signals

A straightforward application of the Ansari, Fiss, and Zajac (2010) depiction of adaptation is to relate each dimension to variance in green qualities adopted for signaling. Organizations making quality improvements for any reason face two broad choices: what type of improvements to make, and how many improvements to make. The more variance in this, the more noisy a subsequent signal may be. When implementing a practice already adopted by others, organizations often try to follow best practices, replicating the success of lead adopters. Replication can also result in mimicry of some prototypical form, which may not be the easiest nor the most effective (Baron, Hannan, and Burton 1999, DiMaggio and Powell 1983).

For example, early adopters face uncertainty about the best way to gain certification. To avoid the risk of being denied certification and losing the opportunity to signal, early adopter ensure that sufficient quality can be demonstrated by making additional improvements beyond the required level. Though later adopters have more information and have less need for these buffer points, they may mimic this practice, faithfully replicating the buffer between the required quality and the quality adopted. That organizations vary in the amount of quality buffering reduces signal fit (Karamanos 2003). However, it is not clear what the appropriate (normative) level should be: while some would argue that the quality should exactly match the requirement in order to derive the greatest signaling benefits, others would see the program as more effective if quality was as high as possible among adopters (Corbett and Muthulingam 2007).

Ultimately, the degree to which organizations obtain excess quality to buffer against the risk of losing signaling benefits is not a normative measure, as there is no objective "best" level of quality relative to the signaling requirements. As a measure of fidelity, the excess quality buffer simply identifies relative differences in adoption. In the context of green signaling, this measure is closely linked to the degree of environmental disclosure. Where the signal sent closely resembles the actual product quality (minimal quality buffering), disclosure is high. At one extreme, those with a great deal of buffering wind up under-disclosing their environmental qualities, in what has sometimes been termed "brownwash" (Kim and Lyon 2015). At the opposite extreme, some may use signals to over-state their actual quality, "greenwashing" their way to a signal. Effective enforcement may limit this, though it's conceivable that those who have obtained the minimum quality for certification are more likely to be greenwashing (Delmas and Burbano 2011). While past depictions of brown- and greenwashing have been highly normative (Delmas and Burbano 2011, Lyon and Montgomery 2015, Gehman and Grimes 2016), we here depict these only as extreme cases along a spectrum of disclosure variance that helps measure the fidelity of practice adaptation.

Measures of relative extensiveness distinguish the opposing axis describing practice adaptation. In the case of signaling, extensiveness may refer to the types of qualities obtained. Some qualities can be experienced by the user, consistent with the traditional expectations on signaling (Lee 2001). Other qualities are often considered desirable but provide public benefits that cannot be directly experienced by the user (Kotchen 2006). These public benefits are often promoted by green signaling mechanisms, which confer elite (club) status to those willing to provide them (Potoski and Prakash 2009). The club theory perspective rewards public good provision with a shared elite identity (Potoski and Prakash 2009), which deviates from the signaling theory view that rewards private quality with private premiums (Spence 1973, Lee 2001).

In pure forms, signaling theory and club theory refer only to purely private or purely public benefits. In the case of green signals, many programs promote a mix of public and private benefits, consistent with the notion of (bundled) impure public goods (Kotchen

2013). Green labels are often obtained through a mix of both. Again, we do not suggest a normative level of either public or private benefits that should be adopted by signalers, particularly because the ideal form that sustainability takes is not well established (Norton 2015). Rather, we take purely public and purely private practices as the extremes along a spectrum of adoption extensiveness. Together with measures of fidelity, these describe a rough depiction of the variance in green signals. Though most adopters fall in the middle in terms of disclosure and public good provision, the extreme highs and lows may be marked by canonical signal types, depicted in Figure 1.

In this characterization, we see traditional Spence-style signals as imperfectly disclosing privately experienced qualities, with Club-style signals fully disclosing public good provision. Where information about the public goods bundled to a product is under-disclosed, we observe brownwashing. Greenwashing is here taken as the final quadrant; the term here indicates that the qualities disclosed may have been overstated (Kim and Lyon 2015). However, this articulation is somewhat contrived, due to the ambiguity in definitions of greenwash (Lyon and Maxwell 2011).

An alternative set of quadrant labels might depict greenwash as the result of organizations labeling business-as-usual practices, rather than making improvements to gain signaling benefits (Lyon and Montgomery 2015). In this case, the term applies to the region currently occupied by the Spence-type signal. Further, the traditional perspective on signaling does not specify whether disclosure is complete (Spence 1973) or simply sufficient enough to induce the separating equilibrium (Akerlof 1970). If the former, the Spence-type signal occupies the region previously labelled greenwash. The ambiguous distinction between these quadrants limits interpretability, arises from theoretically indistinct constructs, and challenges the assumed orthogonality of this framework design.

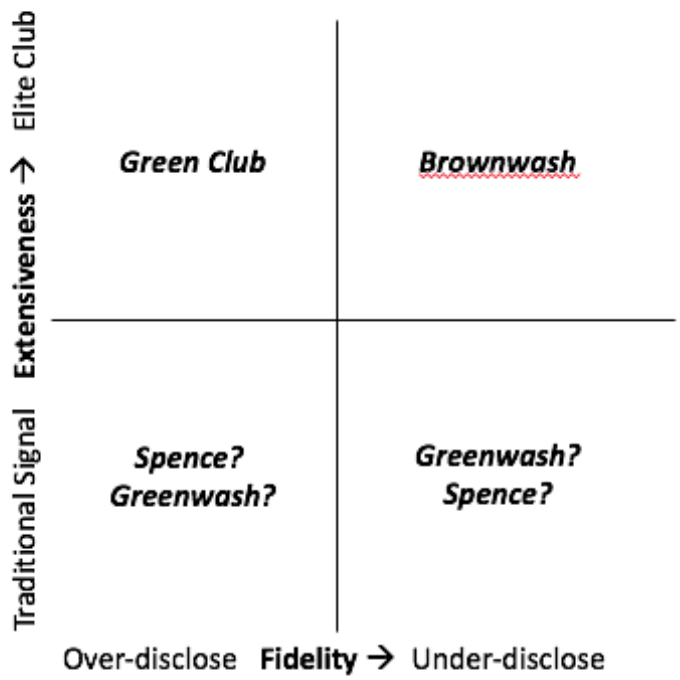

Figure 3.1. Mapping Signal Noise in Two Dimensions.

However, nothing requires fidelity and extensiveness to exist as orthogonal dimensions. Statistically, it seems viable that, lacking a strict upper limit on total quality, any incremental improvements may impact both dimensions (ie, the dimensions are not independent). This is the case for complex goals like sustainability, a quality that may never be completely attained, but may be incrementally worked toward (Norton 2015). Nor should a graphical depiction require orthogonal angles, as alternative mappings are possible. Relaxing orthogonality in our graphical framework for noisy signals, we are able to synthesize a framework that is theoretically consistent with practical demands of measuring sustainability. This is demonstrated in Figure 2, which transitions the dimensions of practice adaptation into a polar grid. In this characterization, changes in one dimension exaggerate changes in the other.

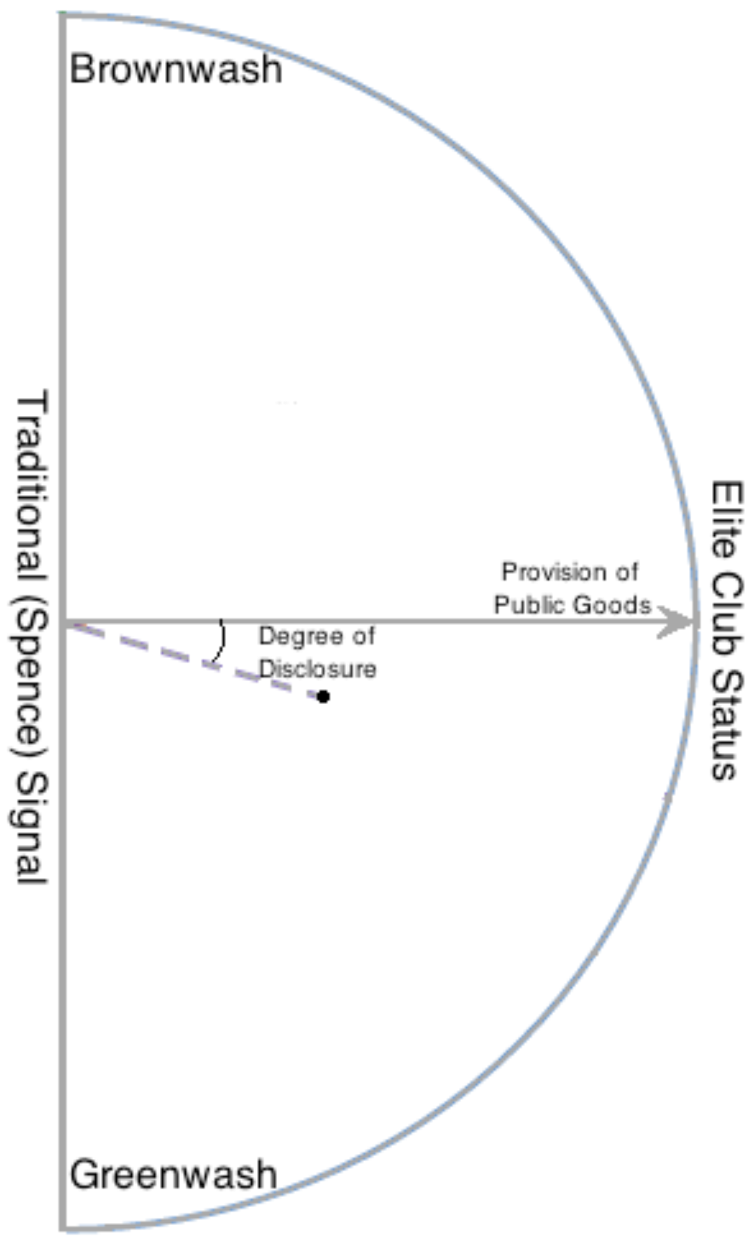

Figure 3.2. A Framework for Noisy Signals. Outer boundaries are defined by the range of available signaling strategies.

In this framework, a signal's position in two-space is determined by a radius and degree. The origin may be interpreted as a traditional signal of performance quality similar to descriptions asserted by Spence (1973). As the radius from the origin increases, we encounter signals that are generated by organizations going out of the way to provide public benefits for elite status. This allows the outer regions of the graph to describe outlier organizations that have chosen high levels of investment in public good, compared to center-of-the-road approaches that more traditionally rely on performance improvements for signaling. The degree of disclosure is then depicted within the framework as a literal degree of rotation around the two-space. Greenwashers, who have overstated their environmental quality, rotate upwards on the graph, while brownwashers, who underdisclose, rotate downward. This allows us to imagine the framework as an analog tuner depicting deliberate practice adaptation for fine-tuned signals of green quality.

So, we arrive at an apt description of how green certification practices are adapted, which synthesizes much of the current discussion about environmental labelling as signaling, greenwash, brownwash, and clubs. Such a framework is of little use if it cannot advance our understanding of green labelling and corporate social responsibility. Further, it must sort the signaling from the noise: is positioning within this framework the result of strategic adaptation, and is that strategy intended to create noise that crowds out reliable quality signals, or is it intended to tune in to tailored needs? We investigate these questions by analyzing data on LEED building certification pathways.

To apply this framework, the constructs of fidelity and extensiveness must first be made measureable. For analysis of LEED building certification pathways, we offer one way to do this. For other signaling mechanisms, alternative measures might be constructed.

Second, extensiveness and fidelity must be predictable. We offer prediction through stakeholder theory; we leave direct tests of other hypotheses from propositions based on institutional sociology (Zajac) to later work. In doing so, we demonstrate that positioning of signals within the framework is strategic, rather than random. Third, the extent to which strategic positioning enhances or undermines the effectiveness of the signal must be tested.

3.4 Signaling in the Built Environment

The US Green Building Council (USGBC) emerged from a network of stakeholders interested in promoting greener and more socially responsible practices in the built environment (cite web). Its Leadership in Energy and Environmental Design (LEED) certification program was launched at the turn of the millennium, with the goal of correcting market failures, namely externalities and information asymmetries (Matisoff, Noonan, and Flowers 2016). The certification acts as a market signal of building quality, has diffused broadly (Kok, McGraw, and Quigley 2011, Kok and Holtermans 2014a), and has been associated with premiums such as improved rental and sales premiums (Eichholtz, Kok, and Quigley 2010a, Deng, Li, and Quigley 2012).

To obtain LEED certification, builders must make and verify improvements to their building, going beyond business-as-usual technology and design to mitigate environmental footprints of the building. Final certification is tiered, with each tier corresponding to a score or credit total built up from each improvement. To earn credits, builders choose from a flexible menu of improvements to the building's energy, water, material, indoor quality, site selection, and innovative practices. This holistic approach includes some credits which confer private benefits (such as energy efficiency), whereas others do not (such as habitat protection). Environmental performance of LEED buildings increases with each additional credit earned, but the signaling benefits of LEED only accrue as builder's reach a higher tier of certification (Matisoff, Noonan, and Mazzolini 2014).

In evaluation literature, programs and certification systems are typically treated as homogeneous black-boxes. By opening this black box, we can observe the heterogeneity in how certifications are adopted, or rather, adapted. In doing so, we can apply the framework for noisy signals to LEED certification pathways. A dataset of approximately eight thousand certified buildings over a decade was made available by the USGBC for the purposes of this study. The data describe building characteristics (location, size, primary use), owner characteristics (market sector), and certification information (LEED credits adopted, score and tier, time of certification, and time of declaration of interest in certification). The dataset constitutes all buildings labeled within the same (new construction version 2.2) certification system during the study period.

3.4.1 Measuring Fidelity

The tiered structure of LEED has induced a saw-tooth distribution of LEED scores, as many adopt certification for marketing benefits (Matisoff, Noonan, and Mazzolini 2014). Those certifying just at or just above are more likely to be motivated by marketing benefits of certification, seeking signaling benefits. By comparison, those certifying well above a threshold are more likely to be motivated by environmental performance motivations (Corbett and Muthulingam 2007, Matisoff, Noonan, and Mazzolini 2014). At the upper ranges of a LEED tier, builders still signal the same quality as those at the bottom of the tier. This creates an under-disclosure of environmental quality, or brownwash. By comparison, those motivated by marketing benefits are more likely to have overstated their environmental performance, in a greenwash (over-disclosure). We may thus measure fidelity as the number of points by which a project exceed the requirement for LEED certification at the project's tier. Conversations with industry experts note that, by default, an organization seeking LEED certification will apply for two or three points beyond their goal, to hedge against potential mistakes. We therefore measure 2.5 points above each threshold as the normal degree of disclosure (zero), with adjustments up or down from there. However, any prototypical reference point is useful only as comparison, not as a normative assumption (Lewis and Seibold 1993). Further, the reference point is fairly arbitrary when cast as an angle in a circle with a beginning determined only by convention. A key assumption, that overshooting a threshold is linearly related with the potential marketing or performance benefits of certification, is later relaxed.

3.4.2 Measuring Extensiveness

A naïve measure of extensiveness would simply be the number of LEED points obtained. However, the program has an explicit goal of encouraging social responsibility so that the public benefits alongside the building owners and occupants. Thus extensiveness is better measured as the public goods provided. All LEED credits confer at least some public benefit by mitigating environmental externalities. Some also cut operational costs, such as energy and water efficiency. Others improve occupant experience, such as indoor air quality and neighborhood walkability. Those which do not confer either type of private benefit are delineated from those that do, as depicted and justified in Chapter 2.

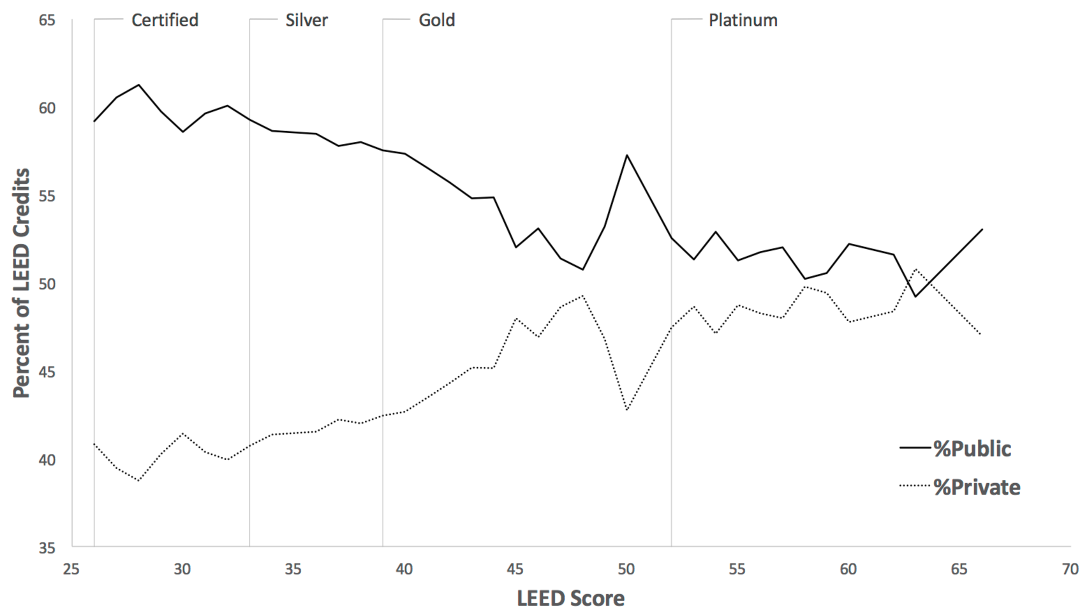

Figure 3.3. Achievement of LEED Points associated with potential private returns versus purely public benefits, as a percentage of total LEED score.

Most LEED scores could be obtained with few credits that offer purely public benefits, if builders maximized efficiency before providing public goods. With this measure, we more directly observe how far out of the way builders go to provide public benefits while seeking certification, consistent with our mapping of public good provision as the radius in our signaling framework. On average, builders do appear to adopt a mix of both at all LEED scores, as observed in Figure 3.

3.5 Predicting Fine-Tuned Signals

Having demonstrated that the framework introduced provides observable measures of fidelity and extensiveness in an application to LEED certified buildings, the next task is to demonstrate the usefulness of the framework in establishing and testing hypotheses. If practices vary in how they are adopted, quality signals are considered noisy (Stiglitz 2000), but this means little if the noise is random relative to expected patterns in motivations and outcomes to adopt. The framework presented is agnostic about these predictions, creating room to apply any number of theories to it. At its most useful, this framework can be used to describe noisy signals as the outcomes of differential motivations to adopt a practice, and can provide independent variables for understanding the outcomes of noisy signals. We begin from the former, leaving the latter to later work.

Can the positioning of signals within this framework be predicted from existing theory? In answer to this question, we may draw on numerous theories to generate hypotheses and demonstrate that the noisy adaptation of LEED certification is rational and strategically motivated. Hypotheses regarding fidelity are first drawn based on expectations for how market structure influences pressures to differentiate products with signaling. Second, hypotheses regarding extensiveness are drawn from stakeholder theory. Other work may more formally investigate the predictive capacity of the framework from information disclosure (Lyon and Shimshack 2015, Gehman and Grimes 2016), public good provision (Kotchen 2006), altruism (Andreoni 1990), and institutional statements (Crawford and Ostrom 1995), among others.

In the private sector, densely populated industries in nearly-pure competition are prone to quality differentiation (Hotelling 1929). Commercial office buildings stand to gain marketing premia for green certification (Eichholtz, Kok, and Quigley 2010a), particularly if they are among the first locally to differentiate with the green label (Chegut, Eichholtz, and Kok 2011). Hospitals and other healthcare facilities practice quality differentiation despite sparse industry populations, largely due to limitations or regulations on price that limit alternative differentiation (Noether 1988). Industries subject to greater public scrutiny and regulation are more practiced in publicly demonstrating changes for compliance, and may even develop a sense of duty after the responsibility of compliance is clearly established (May 2005). Firms experienced with regulators are also motivated to leverage voluntary action to avoid future regulation or legal entrenchment (Maxwell, Lyon, and Hackett 2000), as has been the case for green hotels (Priego et al. 2011). These industries are especially likely to cluster just above thresholds,.

Hypothesis 1: Industries facing greater quality differentiation pressures will maximize disclosure, certifying green with fewer buffer points (decreased fidelity). These industries include commercial office space, healthcare facilities, and hotels.

When choosing the quality improvements to make, firms may consider the stakeholders interested in green certification. Improvements that improve user experience are appealing to potential buyers and tenants, but are not necessarily salient to broader stakeholder classes (Demsetz 1970). As public organizations face more groups of external stakeholders and conflicting environmental demands (Antonsen and Jorgensen 1997), we expect public organizations to deviate in signaling strategy compared to private organizations (Meier and O'Toole Jr 2011), preferring public good provision.

Hypothesis 2: For-profit firms will have a greater share of credits with private benefits (decreased extensiveness), compared to public organizations.

In this hypothesis, we anticipate that commercial office buildings, hotels, heavy industry, and residential homes will follow a more traditional signaling strategy that confers private benefits. On the other hand, governments, nonprofits, schools, and civic groups will provide more public goods when certifying. By considering these dimensions separately, we can begin to predict the overall adaptation of LEED certification pathways to different market sectors and industries. Separate regression models are constructed to predict certification pathway characteristics. Building ownership and building use serve as key independent variables, with controls for building size. Descriptive statistics for each characteristic appear in Table 1. After testing hypotheses, we can map the significant results into the framework, presenting the scatter of signals as the result of fine-tuning, rather than noise. Significant differences in the distribution of certification adaptations across building types can be leveraged to demonstrate the strategic positioning of signals within this framework.

Table 3.1. Descriptive statistics. Mean characteristics by select project types. Standard deviations listed in parentheses. Extensiveness is a function of public goods, as opposed to private goods (qualities experienced by users or through cost-savings).

Type	*N*	Points	Public goods	User exper.	Cost-saving	Fidelity	Size*
All	2,981	38.37	8.67	10.00	16.35	-2.07	113.08
		(6.47)	(2.19)	(2.03)	(4.23)	(2.00)	(250.40)
Gov	1,694	38.67	8.77	9.92	16.58	-2.14	81.88
		(5.96)	(2.10)	(1.97)	(4.05)	(2.01)	(168.57)
Firm	554	37.22	8.29	9.81	15.83	-1.93	222.55
		(7.03)	(2.38)	(2.15)	(4.40)	(1.94)	(417.47)
Non-Profit	496	38.83	8.77	10.37	16.35	-2.10	96.92
		(7.30)	(2.29)	(2.03)	(4.63)	(1.99)	(145.00)
Other owner	237	37.92	8.54	10.22	15.88	-1.92	114.02
		(6.39)	(2.10)	(2.09)	(4.19)	(1.92)	(315.80)
School	653	38.77	8.94	10.26	16.22	-2.02	79.99
		(6.40)	(2.16)	(2.00)	(4.27)	(2.07)	(81.99)
Industry	110	38.03	8.35	9.04	17.08	-2.41	206.68
		(6.21)	(2.14)	(1.95)	(4.36)	(2.21)	(378.84)
Home	170	38.13	8.21	10.55	16.33	-2.05	271.46
		(7.46)	(2.15)	(1.90)	(4.74)	(1.96)	(549.49)
Store	653	38.96	8.78	10.24	16.50	-2.16	124.61
		(7.02)	(2.36)	(2.05)	(4.28)	(2.05)	(233.94)
Healthcare	164	36.55	8.78	10.05	14.53	-1.80	193.36
		(5.79)	(2.09)	(1.85)	(3.63)	(1.67)	(421.09)
Hotel	66	36.75	7.92	10.39	15.36	-1.44	272.99
		(6.69)	(2.42)	(2.27)	(3.86)	(1.63)	(381.70)

*Reported in 1,000's gross square feet. In analysis, ln(Size) is used.

Table 3.2. OLS Regression Models of building qualities and signaling characteristics. Robust standard errors in parentheses; year fixed effects included.

Model	(1)	(2)
Variables	**Extensiveness**	**Fidelity**
Ln(Size)	0.274 ***	-0.044**
	(0.041)	(0.020)
Education	0.244 *	-0.078
	(0.129)	(0.143)
Industrial	-0.168	0.599
	(0.339)	(0.380)
Residential	-0.584 ***	-0.204
	(0.180)	(0.236)
Commercial	0.204	0.120
	(0.136)	(0.138)
Healthcare	0.129	-0.295**
	(0.187)	(0.145)
Hospitality	-0.911 ***	-0.630**
	(0.259)	(0.266)
Government	0.341 **	0.139
	(0.147)	(0.154)
For-Profit owner	-0.256	-0.134
	(0.175)	(0.173)
Non-Profit owner	0.216	0.115
	(0.179)	(0.136)
Constant	5.338 ***	2.496***
	(0.490)	(0.277)
No. obs.	2,822	2,822
R-squared	0.048	0.012

*** p<0.01, ** p<0.05, * p<0.1

Regression results indicate differences between building type and signaling strategy. Table 2 contains results from models describing how ownership and end use drive the fidelity and extensiveness of certification adaptation. The first model describes certification fidelity in terms of the number of points obtained beyond a required threshold. Projects with less fidelity overshoot thresholds by less. The hospitality and healthcare industries are far less likely to achieve beyond minimum certification requirements. While larger buildings also have a tendency towards reduced fidelity, we do not observe any statistically significant differences between ownership types for this dimension of our typology.

Statistically significant results from the second model indicate that government-owned and educational facilities tend to adopt more extensively, producing more public goods compared to other projects. Residential and hospitality facilities certify more through private benefits. As building size increases, so do the public goods associated with project certification, as a percent of total credits obtained in the certification strategy.

With measures of fidelity and extensiveness for each building, we can map the data into the framework. This is depicted in Figure 4, which contains separate panels for the overall scatter of all data, a heat map reflecting the density of observations in each region of the framework, and a characterization of building types typically found in each region of the framework. Because the definitions for brown- and greenwashing are debated somewhat, the boundary conditions of each region are not strictly specified on the graph. However, when we observe a type of building to have a significantly different characteristic compared to the population, we can plot it in the appropriate region.

Typically, statistically differences in characteristics are described in a single dimension (as in Chapter 2). To demonstrate that the populations of each region of the graph systematically vary with regard to ownership or building use, a joint test of statistical differences is needed. To do this, the frequency with which certain types of observations fall near the extremes of the dataset is counted. Table 3 provides a summary of these counts for owner type, which are roughly consistent with hypotheses (e.g., governments adopt more extensively, firms adopt with less fidelity). A chi-squared test of homogeneity

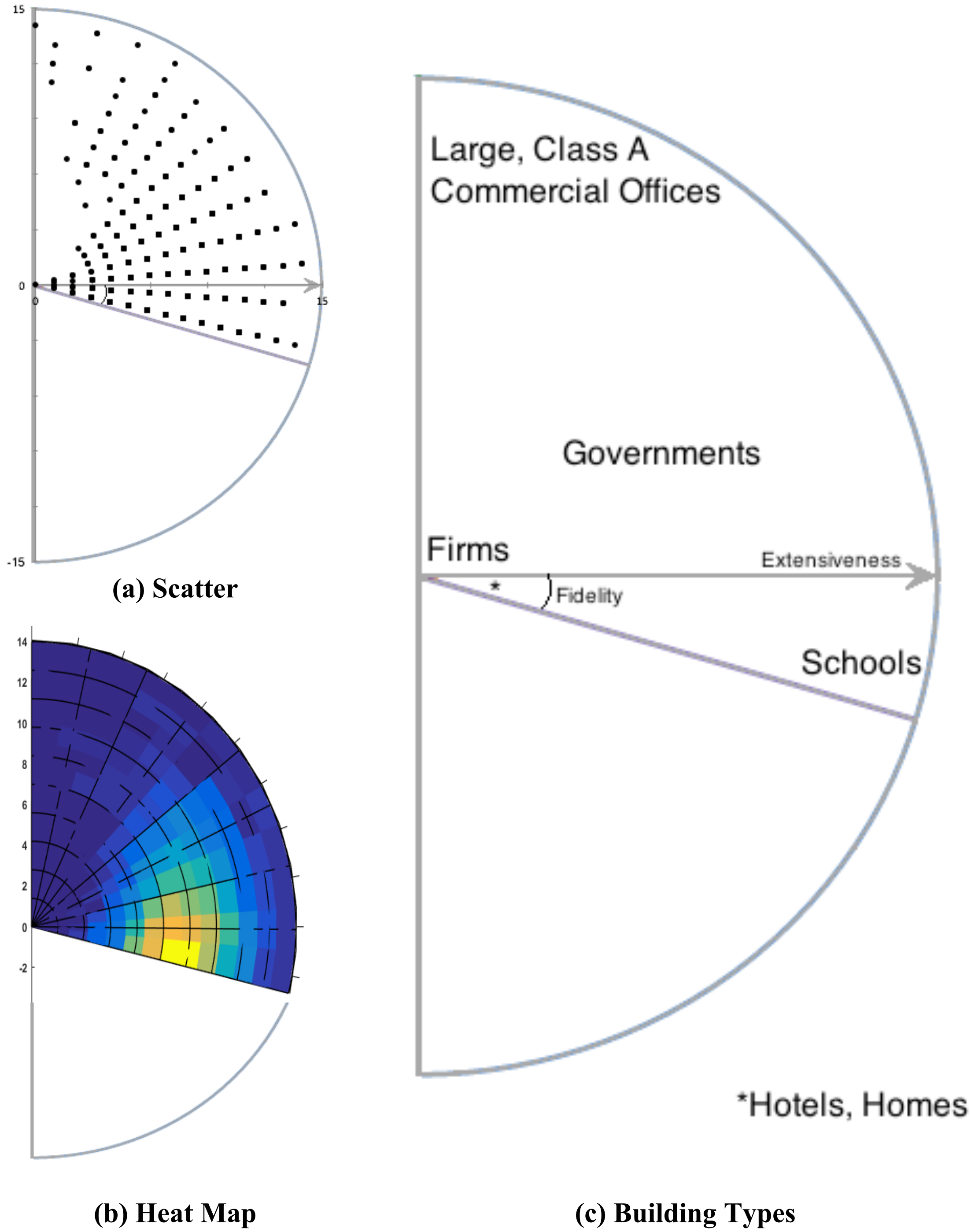

Figure 3.4. Populated Framework for Noisy Signals. Panel (a) depicts the overall scatter of adaptations across the population, (b) shows the density of observations as a heat map, with red regions containing the highest density, and (c) notes where certain types of buildings are likely to be found within the framework. Note that, in the LEED certification system, greenwash is limited by monitoring and enforcement.

confirms that the difference in ownership composition across the typology is statistically significant. With nine degrees of freedom, the chi-squared statistic is 39.16, significant at the 0.001 level.

Table 3.3. How Existing Buildings Fit into the Framework. The percentage of observations belonging to each ownership category is presented for each signaling type. Totals represent the counts of each owner and signaling type.

	Owner Type				
Signal Strategy	**Gov**	**Firm**	**Non-profit**	**Other / mixed owner**	**Totals**
Club	60.12	16.26	16.41	7.21	652
Spence	52.41	20.96	17.85	8.78	706
Greenwash	57.10	19.85	17.10	5.95	655
Brownwash	64.69	11.73	15.31	8.27	810
Totals	1,660	479	469	215	2,823

Thus, the distribution of owners within the signaling framework is not random, and we interpret this as one sign that certification is strategically adapted. A traditional, Spence model of market signals would interpret this variance as noisy signals crowding out the intended quality information and eroding any separating equilibrium induced by the label. Under this framework developed here, such "noise" can rather be understood as organizations adapting a signal, tuning it to their particular needs.

3.6 Summary and Discussion

Under the framework developed for noisy signals, green labelling can be understood as adaptable to specific needs, and, as shown, offers predictive power when integrated with theoretical perspectives. It is not asserted that this framework is a theory in its own right, but rather, provides a useful means of integrating existing perspectives from disparate literatures. Notably, analysis drawing on this framework depends on proper measurement of extensiveness and fidelity. Future work must reexamine the relationship between the constructs and their measurements, in order to relax the assumptions surrounding the models specified above. Specifically, there may not be a linear relationship between a preference for marketing benefits and the number of additional credits adopted beyond a required threshold. And, the stability of the ratio of public goods provided and private goods procured may in fact vary as practices evolve. With improved measures of these two dimensions, we can further assess the framework developed.

The developed measures of fidelity and extensiveness are not unique to the green building industry. Labeling programs usually require participants to surpass some threshold for quality to get certification and its signaling benefits. This means signals accrue discontinuously, though they are based on continuous quality indicators. Though many are binary quality indicators, such as board certification and teacher quality (Goldhaber and Anthony 2007), others share LEED's tiered structure, including bond and credit ratings, restaurant ratings, and numerous multitier ecolabels (Fischer and Lyon 2013, Farhi, Lerner, and Tirole 2013).

The hypotheses presented determine variance in LEED certification pathways as organizations signal specifically to priority stakeholders. Additional hypotheses may be drawn from perspectives on disclosure and club theory, among others. And, the framework can be used to compare signal variance across competing label designs. Alternatively the framework can provide independent variables to predict the effectiveness of signals at conferring market premiums. Under traditional perspectives on signaling, only signals at the origin of the depicted framework hold value in the market: that is, public goods that go unexperienced or unobserved by the user obscure consumer understanding of overall quality as it relates to the signal (Lee 2001, Stiglitz 2000). But, if signals created by generating public or credence goods confer the same (or better) market premiums, a case exists for noisy signals as a strategic tool that does not undermine the effectiveness of the signaling mechanism.

Some research on environmental labelling has found positive financial performance impacts, while others observe no impact or even a negative impact, with a fair amount of debate circling the cause (Koehler 2007). The extent to which noisy signals influence this premium ambiguity warrants consideration. However, with some general evidence that LEED certified buildings do obtain financial premiums, we are poised to assess how certification practices evolve as they diffuse over time.

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CHAPTER 4: LEARNING TO LEED: A RACE TO THE TOP THROUGH SIGNALING

As eco-labels certifications diffuse, it is often unclear whether recent adopters are more green compared to early adopters, or less. Where environmental regulation leads to shifting practices is often discussed as a "Race to the Bottom" or a "Race to the Top." However, the theory of regulatory differentiation does not clearly answer how these races are distinguished, or what forms of regulation might induce a race. Opting for a different perspective based on information asymmetry as a market failure, this manuscript explores how participation in voluntary environmental certification changes over time. By doing so, we assert that information can catalyze a race in a variety of settings. Analyzing Leadership in Energy and Environmental Design (LEED) building certification data, we introduce a methodology for distinguishing propensities to certify for signaling opportunities versus technology improvements. Data demonstrate that over time, organizations and especially firms invest additional resources to attain higher certification, with more attention to specific green attributes.

4.1 Introduction

Voluntary programs and eco-labels are becoming increasingly popular (Darnall and Aragon-Correa 2014), as regulators promote greener practices and as firms seek to demonstrate social responsibility and sustainability. These soft-policy interventions encourage sustainability by distinguishing high quality firms and products, lowering information asymmetries between firms and consumers. In return for participation, organizations hope to accrue market rents. The institutional design of voluntary and information-based approaches to sustainability varies immensely in terms of sponsor organization (Darnall, Potoski, and Prakash 2009), monitoring and enforcement (Potoski and Prakash 2009), and scope of behaviors governed. For example, the government-sponsored Energy Star label addresses only the energy efficiency of a product, whereas green building labels from nongovernmental groups often address multiple product characteristics, like Leadership in Energy and Environmental Design (LEED) and Green Globes.

Participation in green labelling and voluntary environmental has received scholarly attention as researchers attempt to explain and predict the phenomenon. Much of this work examines environmental outcomes of participation in a voluntary environmental program (Koehler 2007). Evidence on the environmental performance of participant firms has been extremely variable, suggesting effective environmental reform from some programs but not others. To some extent, the mixed evidence may be the result of comparing evidence across cases, where free-riding and greenwashing are either limited or fostered by different program designs (Delmas and Keller 2005). Because studies of voluntary program performance are subject to numerous specification errors (Matisoff 2015), empirical methodology may explain other variation in contrary results from multiple studies of the same program. For example, studies of energy efficiency in green certified buildings have identified higher energy use among LEED buildings, suggesting a rebound effect (Newsham, Mancini, and Birt 2009a). Yet more recent analysis using advanced matching techniques reveals large energy savings related to LEED certification (Asensio and Delmas 2017).

Additionally, some have asserted heterogeneous environmental outcomes arise from distinctions in early and late adopters. The fidelity with which participants implement practices they claim to adopt is often higher in early adoption by market leaders (Ansari, Fiss, and Zajac 2010). As a practice diffuses, latecomers responding to institutional pressures and seeking legitimacy, may be more likely to adopt a practice symbolically (Delmas and Montes-Sancho 2010). Facing market premiums or other rents associated with sustainability, late adopters have further incentive to adopt less substantively (Maxwell, Lyon, and Hackett 2000) creating signal noise that erodes the separating equilibrium induced by green signals (Akerlof 1970).

Taken together, this theory and evidence suggests that voluntary and information-based approaches to sustainability may not maintain their efficacy in the long-run. Yet organizations that sponsor green labels and certifications often claim to be drivers of market transformation. Green building industry professionals often assert that "LEED drove the demand for low-VOC paint," referring to the rapid diffusion of green technology following the diffusion of the green building certification program.[3] The now-commonplace paints, which emit less volatile organic compounds (VOCs), were virtually unavailable in regular markets when LEED began counting the paint towards its certification (though a causal link has not been formally established). The claim that voluntary certification can foster extensive adoption over time stands in sharp contrast to work that notes diminished environmental performance of late adopters (Delmas and

[3] For examples of reports citing this claim, see web resources such as Coatings World (http://www.coatingsworld.com/issues/0414/view_features/low--and-zero-voc-paint-technology/7877), the USGBC website (https://www.usgbc.org/articles/leed-facts), or Chemical and Engineering News (http://cen.acs.org/sponsored-content/pushing-toward-sustainability.html).

Montes-Sancho 2010, Toffel 2006). If true, the claim suggests that voluntary and information-based programs may drive a "Race to the Top" (RTT) in markets.

Can a voluntary measure catalyze a Race to the Top? In this paper, we first discuss theoretical perspectives that suggest how the RTT may come about. The hypotheses that emerge from this discussion are tested using data on LEED certification pathways. To accommodate to LEEDs flexible and multi-tier certification structure, we develop a methodology for measuring the magnitude of shifts in distributions within and across tiers. The discussion concludes with implications for theory, methodology, and practice.

4.2 Racing to the Top: A Critique of Theory

Though the notion of a Race to the Top is common in rhetoric for political reform, and though it provides a framework for discussion in many longitudinal studies, the theoretical mechanism describing what drives a RTT is piecemeal. Most often, RTT is framed as simply the opposite of a Race to the Bottom (RTB). As we will discuss below, it is not clear how the theory inverts. After introducing the limits of the RTB, we turn to other perspectives to develop a more complete theory for the RTT.

In its simplest form, RTB argues that when jurisdictions compete for industry, they must create favorable conditions for industry to thrive (Stewart 1977). If compliance with regulation is costly, the equilibrium policy will be established at the point of least intervention (Drezner 2001, 2007), potentially diminishing social welfare or establishing a "pollution haven." However, jurisdictions may compete along more than one factor, differentiating their regulatory profiles in order to avoid a Race (Revesz 1992). Further challenging the RTB theory, benefits of regulation may outweigh the costs, and prompt others to adopt stricter policy. This may be true where firms obtain private benefits from efficiency improvements associated with regulatory changes. Where social welfare increases noticeably as a result of regulation, a “California Effect,” may catalyze the adoption of more stringent policies. In the latter, the desirability of the cleaner environment noticeable after regulation appears to have catalyzed the diffusion of regulatory policies (Vogel 1995).

Empirical evidence of the RTB is perhaps even more uncertain, with numerous studies confirming and refuting it (Dong, Gong, and Zhao 2012). In an apparent response, recent literature has moved away from the emphasis on the regulatory differentiation mechanism, exploring alternative conditions that could drive the phenomenon. Tensions between competitive local markets and trade across global markets has been offered as a driver of firm behavior both toward and away from improved social responsibility (Mosley and Uno 2007). Specifically, Saikawa (2013) notes the propensity of export pressures to drive adoption of heightened standards for automobile emissions, even in developing countries. This observation counters some conventional intuition that globalization produces a RTB. However, it is not clear whether the observed trend is the result of a Race, or simply diffusion of best practices in policymaking. In a true race, regulations improve incrementally in all locations; by contrast diffusion is marked by the spread of a single policy. In this sense, the so-called “California effect,” is the result of policy diffusion, though it is often discussed as a Race (Vogel 1995).

In addition to the drift in theory and mechanism, recent literature has pivoted with respect to the phenomenon of interest and units of analysis. Policy innovation has shifted governance practices from command-and-control type regulation toward market-based, voluntary, and information-based mechanisms. Studies claiming a Race have begun addressing these non-regulatory interventions. For example, Prakash and Potoski (2006) note that *voluntary* regulations such as ISO 14001 are increasingly adopted in nations with high adoption in major export markets. Work by Bernstein and Cashore (2004, 2007) has emphasized the role of non-state actors, such as industry groups and nongovernmental organizations, as legitimate forms of governance that can drive shifts in behavior within an industry. Throughout their work on non-state market driven (NSMD) governance, forestry certification organizations are depicted as governors of their market jurisdiction, though their efficacy in this role is thought to be contingent on several contextual factors (Cashore 2002). In competitive market conditions, NSMD governance suggests that learning can foster a RTT, at least in some institutional arrangements (Bernstein and Cashore 2007).

This drift in focus offers both a critique of the regulatory differentiation mechanism defining the RTB and RTT literature, and an opportunity to develop an improved theoretical framework. In the following, we eschew the regulatory differentiation mechanism in favor of an information-based catalyst for a Race that depends on learning, and is consistent with recent threads of research. Under this framework, a Race is possible under regulatory and non-regulatory policy approaches, can be fostered in political and market-based jurisdictions, and can be driven by government and non-state actors. Critically, we assert that this theory improves on the extant literature, by offering a logically consistent pathway to both the RTT and the RTB, while suggesting hypotheses that are both testable and falsifiable.

4.3 On Signaling, Learning, and Racing

To synthesize a theory for Racing, we begin by asking why a Race is ever necessary. In well-behaved markets, rational actors behave according to well-behaved preferences in the presence of symmetric information. Policy interventions hoping to induce a RTT need only exist when markets fail; that is, when preferences are complete but cannot be acted upon due to information barriers.[4] In effect, policies provide information signals to correct asymmetries and alleviate market failures. This provides consumers a means to act on their preferences, distinguishing high- from low-quality goods and firms (Akerlof 1970). This can induce quality competition in which firms to respond to the "green" consumers' willingness to pay for more sustainable products by improving environmental quality (Lyon and Maxwell 2008).

Quality competition is predicated on several foundational assumptions. First, a market must be competitive, with limited market power. Second, quality must be ascertainable to consumers; that is, consumers must receive and understand the information signaled by a firm's reputation or a product's label. Without these, firms are capable of exploiting labels, stagnating substantive shifts in behavior (Harrison 1999). Third, quality must confer value to the consumer: no Race occurs when consumers are indifferent to the distinguished quality pools. Fourth, information about quality comes from consistent signals, with signal noise from free-riders or greenwashers limited by monitoring (Delmas and Burbano 2011, Delmas and Keller 2005, Potoski and Prakash 2005a, 2009) and by the costliness of implementing and verifying enhanced quality (Mason 2012). Absent these, information is undermined as a tool for shifting behavior, as observed in studies revealing

[4] Alternatively, the market failure could arise from irrational behavior, or from ill-behaved preferences. Because these are not the focus of existing policy interventions, set these possibilities aside by assuming rational behavior on stable preferences. However, we note that analysis under boundedly-rational conditions provide a potential arena for follow up research.

reduced performance in late adopters of a practice (Toffel 2006, Westphal, Gulati, and Shortell 1997, Ansari, Fiss, and Zajac 2010, Delmas and Montes-Sancho 2010, Kennedy and Fiss 2009, DiMaggio and Powell 1983). For clarity, the assumptions are summarized in Table 1.

With information as a signal that helps firms obtain rent under quality competition, a Race to the Top proceeds as follows. As premiums incentivize higher quality, more firms adopt higher quality practices. With diffusion of these practices, experience accrues and organizations learn. Learning reduces costs (Cohen and Levinthal 1989), which make higher quality more feasible for more firms. As a result, even more firms adopt, and a cycle of learning is iterated that propagates a Race.

Table 4.1. Assumptions of the Learning Mechanism for a Race.

Assumption	**Significance**	**Central Literature**
Rational behavior on well-behaved preferences	Generally assumed	Axioms of Choice
Information is signaled, understood, and preferred	Separating equilibrium leads to market premiums	Akerlof (1970); Spence (1973)
Competitive Market	Limited market power	Harrison (1999); Maxwell, Lyon and Hackett (2000)
No free riding	Costliness to obtain; Enforcement mechanism exists	Mason (2012); Delmas and Burbano (2011); Delmas and Keller (2005); Potoski and Prakash (2005a; 2009)

This cycle propagates, potentially ad infinitum, yet with several caveats. First, diminishing returns to learning (Cohen and Levinthal 1989) may gradually slow the observed Race, with quality asymptotically reaching an equilibrium quality level. Second, as a particular quality enhancement becomes market norm, the standards delineating high and low quality must be reset, such that no pooling equilibrium is reestablished (Akerlof 1970).

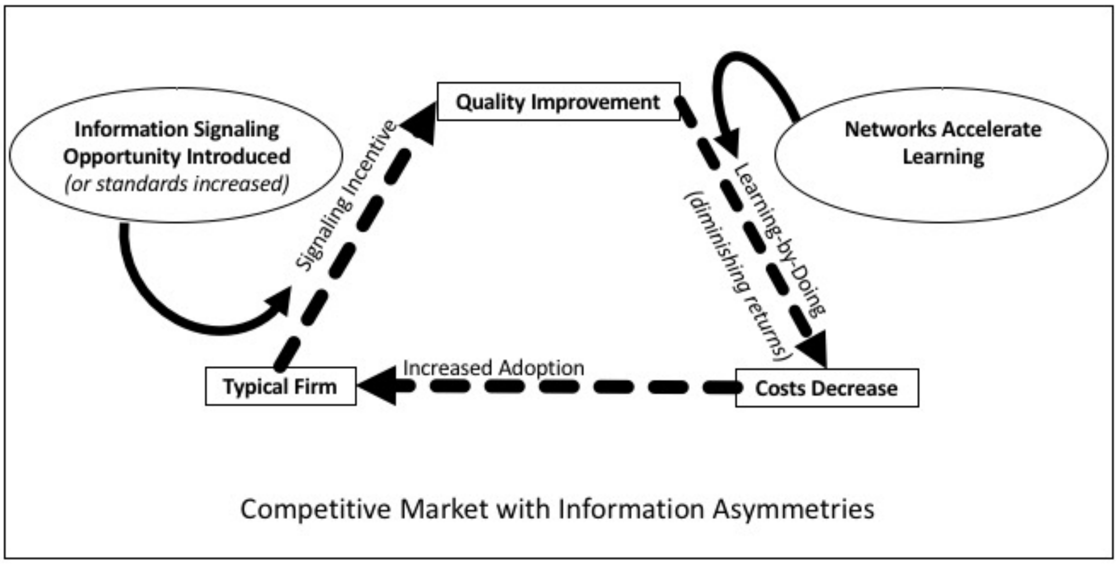

Figure 4.1. Dynamics of Signaling, Learning and Racing in a Competitive Market. Once information is introduced, firms exploit signaling opportunities, learning from quality improvements, and making other improvements more cost-effective. As more firms adopt, the information program must become more stringent, or a pooling equilibrium is reestablished.

Though the language regarding quality competition implies the upward trajectories of the RTT, we assert that this same mechanism points to the RTB. Breach of the assumptions can readily transform an information signal from inducing a RTT to a RTB. When market is concentrated within an industry, competition is inhibited (Harrison 1999). Yet firms may choose to exercise their market power to manipulate signals as a rent-seeking strategy (Maxwell, Lyon, and Hackett 2000). This is observed in industry-sponsored legislation and labeling programs which carry little legitimacy (Bernstein and

Cashore 2004), confer lower returns (Darnall, Potoski, and Prakash 2009), but also generate signaling noise that prevents the RTT. In this setting, policy learning (Jenkins-Smith and Sabatier 1993) helps rent seekers (free-riders or greenwashers) to exploit signals (Maxwell, Lyon, and Hackett 2000) or influence policy processes to minimize regulations that would result in costly compliance (Dal Bó 2006). In this way, the learning perspective on the RTB is closely related to traditional perspectives, though derived from fundamentally distinct mechanism. For completeness, we note that markets also undergo the RTB for bads that consumers prefer not to obtain, though this is somewhat trivial.

This theory is consistent with recent assertions that trade drives the RTT. More precisely, scholars have observed increased diffusion of higher quality practices when markets are networked through trade flows (Prakash and Potoski 2006, Saikawa 2013). Networks have been identified as facilitators of learning in a variety of markets (Desmarais, Harden, and Boehmke 2015, Egels-Zanden 2017, Krackhardt and Hanson 1993, Owen-Smith and Powell 2004), absent extreme embeddedness (Uzzi 1997). Thus, we generally anticipate networks to catalyze the Race through learning.

From the above, we arrive at a new mechanism for a Race based on information signals and learning. Under this framework, we avoid theoretical hiccups of the regulatory differentiation perspective, particularly by providing a path to either the RTT or RTB via a single mechanism. The learning perspective is consistent with recent literature claiming the existence of a Race induced by non-regulatory mechanisms or non-state governance, and that the Race is fostered through networks. With this theoretical lens in place, we are now prepared to answer our original research question. That is, we can now identify tests for the assertion that voluntary and information-based policy approaches can induce a RTT, based on the phenomena denoting a Race.

In its reduced form, any Race is connotes diffusion of a set of practices. This has at times been the key observation from which a Race is (incorrectly) assumed. While certainly a Race is less compelling for policy purposes if it is not widespread, horizontal proliferation is not required for a Race to exist. In the case of markets with concentrated power, vertical proliferation among a few powerful firms can be equally influential in terms of the desired social outcome. Notably, we have asserted that this type of proliferation would seem to foster the RTB. By contrast, in the absence of highly concentrated market power, we anticipate that widespread diffusion is a central characteristic of a Race.

Hypothesis 1. Where conditions for the RTT are met, information signals foster learning to accelerate widespread market adoption of a practice.

Though diffusion is in ways a hallmark indicator for a Race, it is not in itself sufficient proof of Racing. To address this distinction, it is helpful to examine shifts in the extensive and fidelity of practice adoption over time (Ansari, Fiss, and Zajac 2010). In this conceptualization, extensiveness is the degree to which a practice is adopted, whether far-reaching or restricted; fidelity is the degree to which the adopted form of the practice matches past iterations or original intent. As orthogonal dimensions of practice adoption, extensiveness and fidelity are treated separately in terms of a Race. This distinction varies from past treatments of Racing, in that previous literature rarely acknowledges heterogeneity of adoption, treating participants as uniform adopters. Because a RTT requires iterative gains in performance or quality, the RTT predicts extensiveness dimensions increasing over time.

Hypothesis 2. Where conditions for the RTT are met, information signals foster learning to accelerate increased extensiveness in practice adoption.

Recalling that the RTB is possible when signaling is manipulated to accrue rents with deceptive information, it is important to distinguish the RTB from the RTT. We can do this by further leveraging the extensiveness and fidelity of diffusing practices. In the RTB, extensiveness is strictly non-increasing. This does not suggest that the RTB requires diminishing extensiveness, but that, if extensiveness is stable, the RTB could emerge from diminished fidelity. In some sense, diminishing extensiveness with diminishing fidelity may be the "strong" form of the RTB, in which practices worsen social outcomes in time. The "weak" version of the same requires only one dimension to diminish. The RTB may occur through stable extensiveness and low fidelity, observed as gaming signals through symbolic adoption, free-riding, or greenwashing. Or, the RTB may occur through stable fidelity and low extensiveness. This phenomenon has been called a "Race to the Bar" (Wagner 2013). Notably, Ansari, Fiss, and Zajac (2010) argue that a variety of conditions may determine extensiveness and fidelity of practice adoption, including cases of increased extensiveness with low fidelity. These are independent of a Race over time.

Hypothesis 3. Where conditions for the RTT are met, information signals foster learning to accelerate increased fidelity in practice adoption.

Tests of these hypotheses, and particularly tests that distinguish extensiveness from fidelity, require advanced empirical approaches. Moreover, a thorough examination requires data from markets in which the expressed conditions are largely met, in which information asymmetries exist but have been ameliorated through a policy program, and in which multiple years of data are available. We first introduce one such setting, then develop a methodology that differentiates extensiveness and fidelity.

4.4 Empirical Setting: LEED Certification

In the real estate market, buyers (and tenants) prefer qualities like energy efficiency, healthy indoor environments, and often prefer sustainability. Yet because many of these qualities cannot be directly observed by the prospective buyer, information asymmetries have inhibited adoption of greener building practices (Matisoff, Noonan, and Flowers 2016). In response, the US Green Building Council (USGBC) was founded in 1993 as a private organization that promotes sustainability in the built environment by operating the LEED certification program.

Certification standards are set and frequently updated by vote of the open-membership. These standards address all aspects of the building's interaction with the environment, from construction material sourcing to occupant energy use. As a network, the USGBC membership consists of institutional and individual stakeholders from across diverse industries associated with construction, real estate, and the built environment. The organization invests in diffusing an understanding of its label by training professionals, who can obtain an Associated Professional (AP) credential after passing examination. USGBC members further interface with a federated system of international green building councils to facilitate diffusion of sustainable design practices.

Even without a national green building regulation, the voluntary label has diffused quite rapidly labeling as much as 30 percent of commercial real estate space in rapidly growing cities (Kok and Holtermans 2014b). This success has been attributed in part to

LEED's straightforward role as a signaling tool. Perhaps not surprisingly, rental and sales premiums tend to increase with certification (Eichholtz, Kok, and Quigley 2010a). Because financial premiums increase as firms move up the tiers of certification (Eichholtz, Kok, and Quigley 2010b), organizations have incentives to certify at the minimum of their respective threshold, obtaining just enough LEED credits to get the desired premium.

A building may become LEED certified if designers verify a variety of improvements to the building's holistic environmental footprint for a third-party monitor. This monitoring limits free-riding (Delmas and Burbano 2011, Delmas and Keller 2005, Potoski and Prakash 2005a, b, 2009), alongside the additional costs of green construction and the direct costs of certification (Mason 2012). Thus, in pursuit of certification and its benefits, builders must demonstrate improvement to the building's energy or water efficiency, site sustainability, material use, and design innovations. For each improvement demonstrated, the project earns "credit" or points towards a LEED score, measured continuously. After receiving 40 percent of total possible credits, a building can be certified. Higher certification tiers are awarded for reaching 50 (Silver), 60 (Gold), and 80 (Platinum) percent of credits available. The arbitrary thresholds are not natural cut points in building technology investment, and because organizations can choose from a broad menu of options, organizations retain significant flexibility in choosing across different technology investments at all levels.

The tiered structure of LEED certification provides space for differentiation of extensiveness from fidelity. First, extensiveness may be observed as the continuous differences in LEED scores. Second, the tiers provide incentives to overstate sustainability in pursuit of signaling benefits. The distribution of LEED scores resembles a sawtooth pattern, with a plurality of observations at or just above certification thresholds, but a nontrivial density of buildings with point totals far from thresholds (Matisoff, Noonan, and Mazzolini 2014). Past work has suggested that, while those who obtain a LEED score that precisely matches a minimum requirement pursue marketing benefits, those who certify well beyond these minima do so for the performance benefits of additional sustainability (Matisoff, Noonan, and Mazzolini 2014). Because environmental performance is key to the USGBC's original aim, those who certify well beyond thresholds are considered to have greater fidelity in their adaptation of the LEED certification system. Thus the distance between the tier threshold and the final LEED score reflects whether organizations oriented their decision making around the signaling scheme or the building's environmental performance. By measuring the extent to which building projects occur closer or farther away from the thresholds over time, we measure the extent to which fidelity shifts.

The tiered structure of LEED is not unique. Rather, tiered certifications and ratings are ubiquitous across industries, including restaurant safety ratings, bond and credit ratings, and several multitier ecolabels (Farhi, Lerner, and Tirole 2013, Fischer and Lyon 2013). This tiered program design helps provide more detailed information about product quality but still resembles a stacked binary signal, where the threshold to reach the next tier represents a distinct pass/fail determination. The tiers provide greater information compared to binary certifications, but create challenges in assessing changes in the distribution of green buildings (Matisoff, Noonan, and Flowers 2016).

It can also be difficult to distinguish which builders certify for performance or marketing schemes, since the performance benefits increase monotonically with LEED scores, but marketing benefits accrue in discontinuous fashion. And, organizations do not have to certify for only one of these benefits. Discussions with LEED builders and consultants suggest that some firms, after targeting a certification level, may consider additional cost-effective investments within that tier. Alternatively, other firms may plan the cost-effective credits first, and then decide if it is worthwhile to bump up to the next highest threshold. Additional complexity arises when those who prefer marketing benefits are risk averse. These builders ensure that they obtain a specific certification tier by buffering their scores with extra (typically two) points, scoring among those focused on performance benefits.

Because the LEED label fits most of the essential assumptions necessary for a Race, we expect learning to occur. This may happen in two ways, which are not mutually exclusive. First, organizations learn about the structure of the ecolabel and how to strategically minimize effort while maximizing the marketing benefits associated with ecolabel participation (Lyon and Montgomery 2015). This is suggestive of the RTB. Second, organizations learn about the value of the practices and technologies that underpin the ecolabels themselves and how to select and implement appropriate technologies. Learning that improves environmental performance is indicative of the RTT. After checking for diffusion (accelerated adoption) and increased extensiveness (higher LEED tiers), we develop a notches methodology that distinguishes relative weights for marketing and performance benefits in the distribution over time to examine evidence of shifting fidelity, characteristic of a Race.

4.5 Data: LEED Certification over Time

Data are obtained from the USGBC's complete listing of all LEED certified buildings in the United States. The available data include LEED point total, certification level, project name and address, LEED scoring system used, project type, buildings size, and site context. We restrict our analysis to the buildings within the LEED New Construction (LEED NC) versions 2.0–2.2, in which building scores are computed similarly, in order to maintain consistent reference points for certification and simplify results to comparable metrics based on a single set of building codes.

Under LEED NC 2.0-2.2, buildings must achieve at least 26 points to become Certified, at least 33 points for a Silver certification, 39 points for Gold certification, and 52 points or more. On average, buildings score 37.3 LEED points, though non-profits score higher (38.1 points on average) compared to government and for-profit entities (averaging 37.5 and 36.4, respectively). In the LEED NC sample, 19.4 percent are Certified, 33.4 percent are Silver, 40 percent are Gold, and six percent achieve Platinum.

The frequency of LEED buildings at all certified scores is displayed in Figure 2. About 46% of buildings earn point totals that are either at or just above these certification thresholds. Building scores that are just below each threshold are rare. The extreme lumpiness of these data likely do not result from an underlying smooth distribution, but rather from the discontinuous signaling benefits that accrue at each threshold (Matisoff, Noonan, and Mazzolini 2014).

We divide our data into categories by owner type and building use. Of the 4,486 total projects, 2,039 are owned by government agencies, with a little over half of these owned by federal or state governments and the remainder by local governments. For-profit entities own 1,445 of the buildings, and non-profits own 1,018. Buildings are also separated by primary use according to the information provided to the USGBC at the time of LEED registration and certification. This partitions buildings by whether they are put to use as commercial office (N=1,338), retail (427), healthcare (268), restaurant (159), hotel (92), or schools at the local (513) or higher education (773) levels. Altogether, commercial buildings make up 1,758 observations, or almost 40% of our data.

4.6 Early Evidence of Diffusion and Increased Extensiveness of LEED Adoption

From the stated hypotheses, we expect that LEED, as signaling tool in a market that approximates the conditions required for the RTT, fosters learning. So, we anticipate (1) widespread diffusion of the standard, (2) increased extensiveness of certification, and (3) increased fidelity of certification pathways to the original aims of the program. To the first, numerous studies confirm the widespread use of the LEED label, in the US and abroad (Kok and Holtermans 2014b). Our data confirm the trend: each year, the number of new buildings added under the LEED-NC 2.2 certification standards grows, peaking just after 2010, when a new version of LEED-NC (v2009) standards was initiated (observations in this new version are excluded from study, though it may have been pursued by some high achievers during the period of study).

Though the diffusion of a practice can be measured as a straightforward frequency, extensiveness and fidelity are not so simple. A rudimentary measure of extensiveness may be simply the LEED score or corresponding certification tier. The distribution of LEED certifications generally increases at higher scores and tiers over time. Figure 3 demonstrates that roughly one-third of buildings certify at the Silver level during each of those years. The annual portion of buildings certifying Gold rose from less than 25 percent to over 40 percent of new buildings over the period from 2005 and 2009. The portion of buildings certifying Platinum remains between about five and seven percent each year, although the number of Platinum buildings added annually grows almost every year. Notably, 2008 seems to be an outlier year, where Gold certification dropped and Silver spiked.

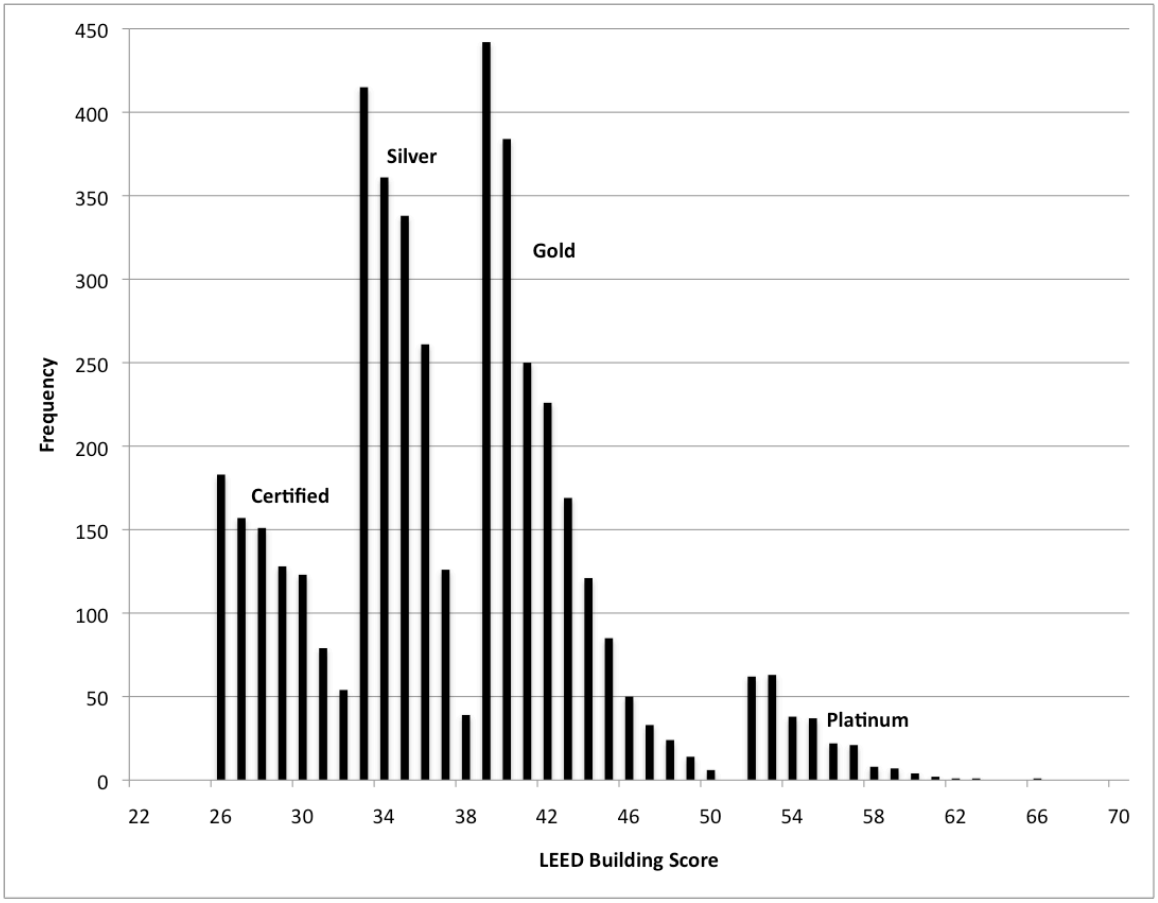

Figure 4.2. Observed distribution of LEED building scores.

Though Figure 3 might appear to support Hypothesis 2, this is not sufficient to demarcate the RTT. In addition to the increasing extensiveness, we require a distinct measure of fidelity. Past analysis of the tiered LEED certification structure reveals that, at any particular LEED score, the decision to adopt is driven by a mix of both environmental (or energy) performance improvements and signaling (or marketing) benefits, and that the observed distribution is extremely unlikely without this mix of motivations (Corbett and Muthulingam 2007). The average extent to which signaling versus performance motivates adoption has been identified with an adapted regression discontinuity approach (Matisoff, Noonan, and Mazzolini 2014). We build on that methodology to examine shifts in motivations over time. Given support for Hypotheses 1 and 2 suggests the existence of a Race, we take evidence on the shift in motivations as the distinguishing factor for a RTT or RTB. That is, if the prevailing motivations for certification trend towards performance over signaling, we observe the RTT. If the converse is observed, trends are consistent with the RTB, as signaling and marketing benefits drive adoption with less fidelity to the original aim of environmental performance.

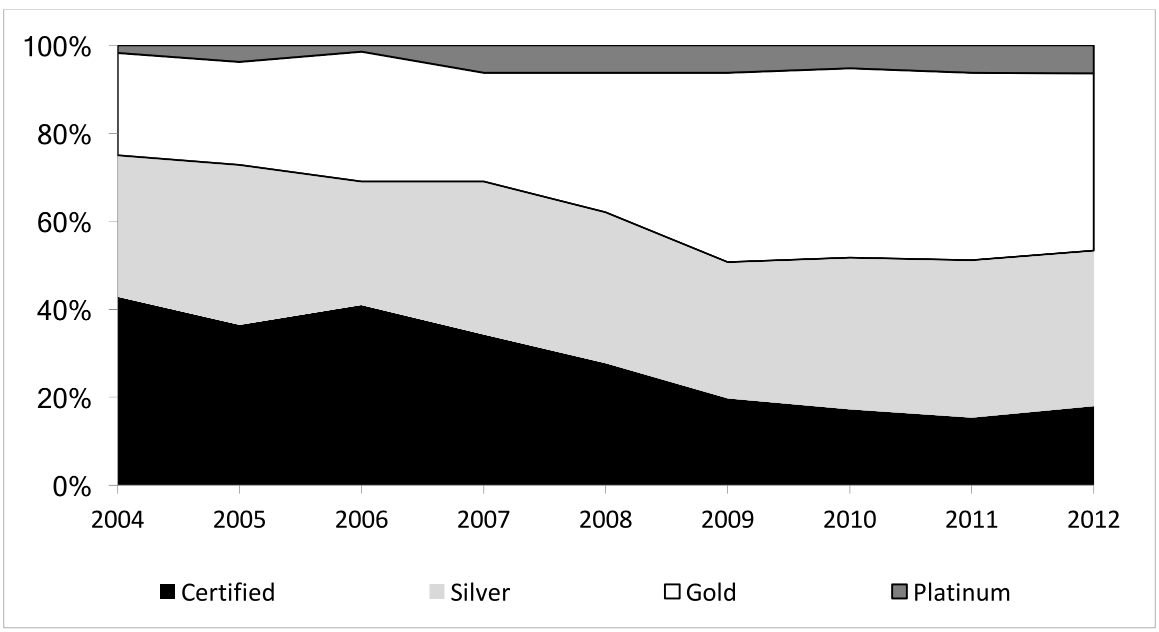

Figure 4.3: Changes in certification level distribution for years 2004-2012.

4.7 Method: Distinguishing Extensiveness From Fidelity

Measuring the extent to which marketing and performance drive adoption is nontrivial, especially in a multitier setting like LEED. Following Kleven and Waseem (2013), we begin by constructing a counterfactual distribution in the absence of the multitier thresholds, without making restrictive or theoretical assumptions about how that counterfactual should be shaped. The counterfactual imagines a setting without signaling schemes; only project attributes drive the counterfactual distribution. This counterfactual allows us to compare the observed distribution to a plausible, conservative estimation of what would have occurred in the absence of tiered thresholds. Thus, the counterfactual is a conservative estimation of the distribution created when performance drives all certification, and excess density in the observed distribution is explained by marketing motivations.

After characterizing the extent to which marketing drives the observed distribution and comparing across building types, we observe how these changes with time. We test for these trends across owner types and building uses. If greater performance motivations drive the certification, we observe improved fidelity, and conclude the RTT has been induced by the voluntary information program. If greater emphasis is placed on signaling benefits, we observe diminished fidelity, we conclude the weak form of the RTB.

4.7.1 Measuring Signaling and Performance Motivations in a Tiered Setting

First, to determine the extent to which signaling (marketing) benefits drive certification, at each possible LEED score, a counterfactual distribution of LEED buildings is constructed to describe a hypothetical distribution of buildings where no certification thresholds exist. In this counterfactual distribution, building attributes are described only by the continuous LEED certification score. A key assumption in this analysis is that the benefits from specific project attributes increase with each additional LEED point, and are locally smooth around certification thresholds. Following the notches methodology employed by Kleven and Waseem (2013), a locally smooth polynomial function is generated based on the observed distribution of buildings with LEED scores.

If LEED building scores reflect only benefits related to LEED building performance, excluding signaling benefits accruing discontinuously around the certification thresholds, the observed distribution would be smooth, peaking in density at the average score that is cost-effective on building performance grounds alone (Corbett and Muthulingam 2007). In Figure 2, we observe an abrupt jump in frequency at each threshold, with far more signaling driving certifications just above a threshold, and very little performance driving certification immediately below the threshold. In constructing the counterfactual, the regions above and below the cutoff are effectively dropped, eliminating the pronounced discontinuities visible in the observed distribution. We then generate a locally smooth polynomial based on the remaining observations, creating a feasible and empirically determined counterfactual distribution to approximate a distribution unaffected by strategic behavior around the thresholds. If signaling does not affect the observed distribution, the counterfactual imagined would be a near-perfect match of the distribution observed in Figure 2.

The construction of this polynomial is sensitive to the bandwidth selected for local smoothing, the degree of the polynomial employed, and the range of LEED scores omitted around the thresholds. A tradeoff exists between matching the observed distribution and generating a smoother counterfactual. It is important that the counterfactual match the observed distribution over regions between thresholds, where observations' scores are most closely tied to the building's environmental performance. To make the counterfactual more closely shaped to the observed distribution, omitting fewer scores around the thresholds and maintaining a smaller bandwidth is preferable.

By contrast, a smoother polynomial, derived by dropping more of the observed distribution while constructing the counterfactual, is closer to some expectations of a distribution without signaling.[5] And, many seeking marketing benefits will buffer their LEED scores, ensuring attainment of a particular LEED tier. Omitting more of the distribution from the counterfactual prevents these signalers from entering the performance distribution. In turn, which would skew results by inflating the counterfactual densities at and just above thresholds, and deflating the appearance of excess density due to scheme orientation. Tighter windows of omission thus give a more conservative estimate of tier effect signaling. By contrast, a larger window makes the counterfactual smoother or consistent with theoretical priors, but draws less on the empirical density.

For this analysis, we drop building scores within two LEED points of the threshold and estimate a second-degree locally-smoothed polynomial over the remaining data, selecting a bandwidth of two. This bandwidth choice enables us to select a point value (which may or may not serve as a certification threshold), and smooth over the observed distribution of buildings at that value, the value above it, and the two below it. Dropping a

[5] Corbett and Muthulingam (2007) contend that a distribution driven by attribute orientation must be unimodal. The authors impose various distributions to determine the most appropriate explanation for the empirical multi-modal LEED distribution. We remain less restrictive about the shape of the expected distribution, simply estimating a smooth distribution based on the empirical distribution, excluding the observations around the thresholds.

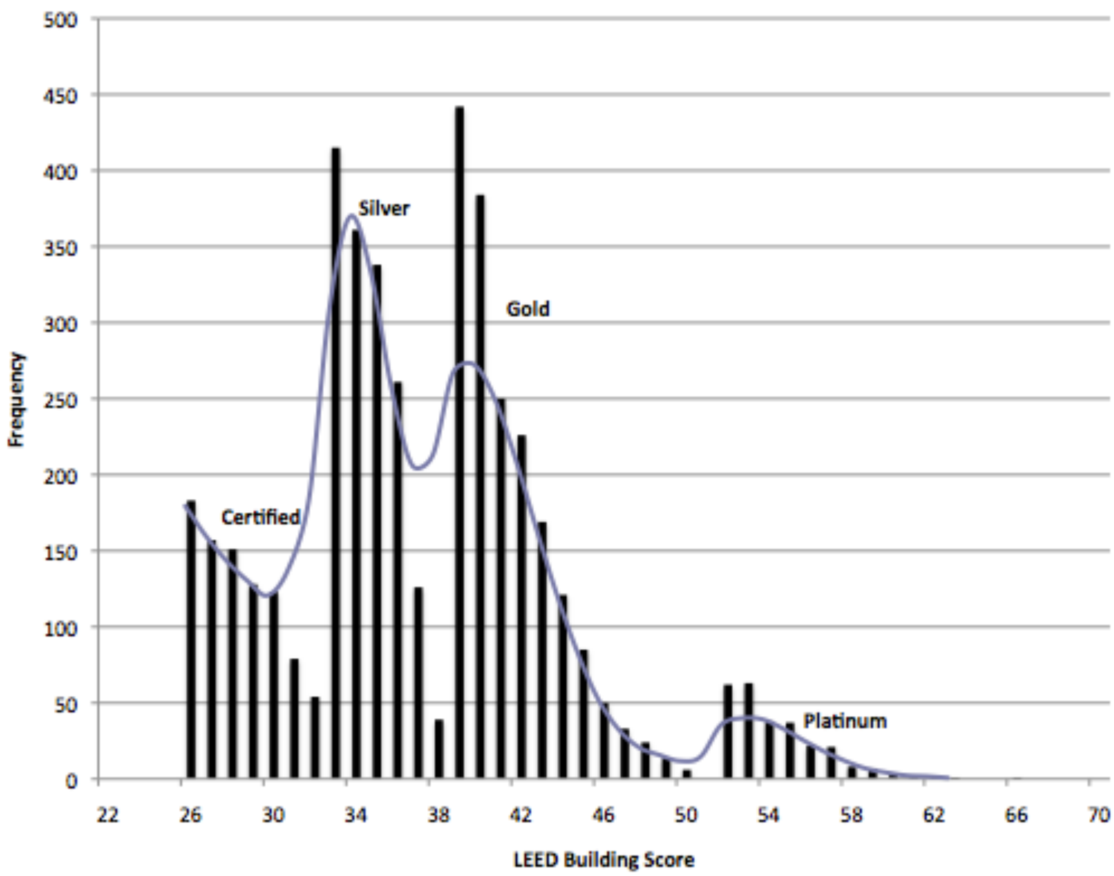

Figure 4.4. Observed and counterfactual building distributions. Counterfactual distribution constructed with locally smoothed polynomial.

larger window is infeasible, because there would be little density left in between thresholds left to estimate a counterfactual. Matching the bandwidth to the window of dropped scores enables interpolation of a smooth distribution over the region of missing observations, though an alternative bandwidth is explored in the robustness checks.[6] The resulting polynomial creates a counterfactual distribution of LEED buildings that is conservative with respect to its theoretical presumptions and is consistent with our discussions with

[6] Robustness checks contain results based on a bandwidth of four, which appears more similar to a Normal or Chi-squared distribution, though still maintains local maxima in the Certified and Platinum tiers.

green building professionals (LEED AP community) regarding the extent to which organizations buffer their scores.

The observed and counterfactual distributions are graphed in Figure 4. The counterfactual distribution, describing a distribution without marketing motivations, is compared to the observed distribution, which includes both marketing and performance motivations. Marketing drives the portion of the observed frequency that exceeds the counterfactual at each LEED score. For each score, we difference the distributions, and divide by the number of observations composing the observed frequency. This calculation estimates the relative revealed preference for signaling benefits above marketing benefits for each LEED score. The unique values are distributed across each building with that score. To avoid double-counting, and because we are interested only in the *excess* of buildings above thresholds due to signaling motivations, values are censored to preserve only nonnegative values.

The average relative revealed preference (*ARRP*) for signaling at each LEED score *i* can be defined as:

$$ARRP_i = (n_i - c_i) / n_i \qquad (1)$$

where *n* is the number of buildings observed and *c* is the counterfactual frequency. Thus, a building scoring at or just above a certification threshold, where the observed frequency is much higher than expected by the counterfactual, reveals a very high signaling preference. If the frequencies observed in the data and predicted by the counterfactual are similar at a given building's score, buildings in that range of the distribution reveal little or no signaling preference, marked by a value close to zero. These observations are considered more performance motivated. Because this definition simply implies that the densest points in

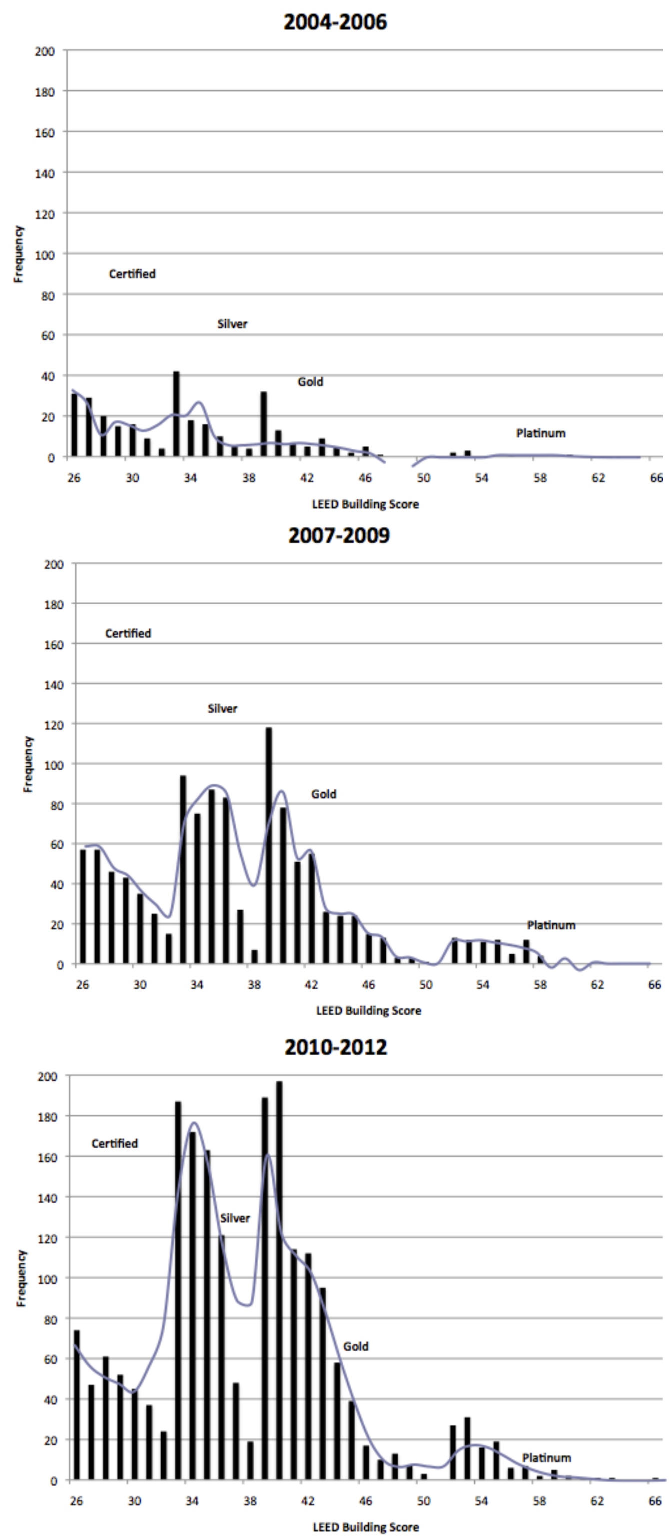

Figure 4.5. Changes in LEED NC score distribution over time. A locally-smooth polynomial, calculated in the same fashion as the counterfactual used throughout this work, is superimposed over the data in the time period for each histogram.

the observed distribution will correspond to high signaling preference, and the low density regions of the distribution correspond to low signaling preference (greater performance preference), our results remain consistent across a wide range of potential counterfactual functions, as demonstrated in the robustness checks. After revealing signaling preferences for each LEED building score, we calculate aggregate revealed preference across tiers ($\Sigma ARRP_i n_i$ for all i belonging to *Tier*, divided by observations certified at *Tier*), and for subsamples of particular building and owner types. Averages draw on counterfactuals derived from the entire sample.

4.7.2 Signaling Preferences over Time

Next we observe changes in the prevailing preferences over time, overall and by owner type. This lets us determine whether signaling or performance motivations comes to dominate, and whether trends are consistent for each level of certification. Shifts in motivations provide evidence regarding the potential Race that may arise when learning occurs. To know that increased adoption is not simply the result of greenwashing, we must observe increased preferences for performance, or decreased preference for signaling.

Such calculations require the composition of separate counterfactuals for each of the years of interest. We generate counterfactuals for several time periods, based on only on observations in subsets of years. Results are depicted graphically in Figure 5. We assess trends over time by calculating the *ARRP* for each year T, including only observations in year $t \leq T$. We also compute these trends for subsamples based on owner types, referencing the counterfactual derived with the entire set of buildings certified prior to T.

4.8 Results

Signaling *ARRP*s are assigned to each building based on the counterfactual distribution obtained from the locally smooth polynomial. Results demonstrate that many LEED buildings cluster at and above each certification threshold (seen in Figure 2), suggesting strong signaling preferences for buildings certified at these LEED scores. Few buildings attain scores just below the threshold, where performance motivations dominate and signaling motivation is minimized. Figure 4 displays the distinction between the observed sawtooth distribution that occurs in the presence of signaling preferences, and the counterfactual distribution constructed entirely on building performance. The counterfactual is a conservative estimate, likely undervaluing signaling preferences by underestimating the extent of signaling motivations. Results in the robustness checks depict a less conservative smoothing bandwidth of four, which creates a nearly unimodal distribution and produces large estimates of scheme orientation.

4.8.1 Variation by Building Owner and Use

Table 2 displays the aggregate revealed preference for signaling among all observations, and for various subsamples defined by the building's owner type, certification level, or end use. For all 4,486 LEED buildings, a little over 2% motivated by signaling at the Silver tier, versus almost 6% at the Gold tier, and 1% at the Platinum tier. Put another way, at least one in ten LEED-certified buildings have upgraded to the next higher threshold due to a signaling benefits. (Our alternative counterfactual, described in the robustness checks, estimates that signaling motivates 17% of adopters.)

All subsamples demonstrate some signaling preference, relative to performance preference. Results for all owner types show more signaling at the Platinum and Gold tiers, highlighting the role of information signals in motivating the greatest improvements. This trend is especially pronounced for the for-profit subsample, with 16.7% and 19.3% of Gold and Platinum certifications motivated more by signaling than performance.

Table 4.2. Signalling Preferences by Subsample. Percentage represents excess share of certified buildings motivated primarily by signaling benefits.

		Aggregate Revealed Preference for Signaling				
Group	**Size**	**Certified**	**Silver**	**Gold**	**Platinum**	**Net**
All	4486	0.03	2.26	6.22	1.11	9.62
Federal / State Government	1057	0.03	2.06	6.85	1.22	10.15
Local Government	985	0.03	2.33	5.80	0.99	9.15
For-Profit	1445	0.04	2.43	6.03	0.86	9.35
Non-Profit	1018	0.03	2.14	6.24	1.47	9.88
Certified	870	0.16	0.00	0.00	0.00	0.16
Silver	1542	0.00	6.57	0.00	0.00	6.57
Gold	1806	0.00	0.00	15.45	0.00	15.45
Platinum	268	0.00	0.00	0.00	18.53	18.53
At Least Silver	3616	0.00	2.80	7.72	1.37	11.89
At Least Gold	2074	0.00	0.00	13.45	2.40	15.85
For Profit Certified	340	0.15	0.00	0.00	0.00	0.15
For Profit Silver	518	0.00	6.79	0.00	0.00	6.79
For Profit Gold	523	0.00	0.00	16.65	0.00	16.65
For Profit Platinum	64	0.00	0.00	0.00	19.31	19.31
Profit- At Least Silver	1105	0.00	3.18	7.88	1.12	12.18
Profit- At Least Gold	587	0.00	0.00	14.83	2.11	16.94
Higher Education	773	0.03	1.90	7.47	1.77	11.17
Local Schools	513	0.03	2.43	5.61	0.76	8.83
Health	268	0.04	2.28	6.77	0.48	9.57
Hotel	92	0.02	3.98	6.96	0.86	11.82
Restaurant	159	0.04	2.77	7.03	0.77	10.61
Retail	427	0.03	2.12	5.72	0.85	8.72
Office	1338	0.03	2.19	5.76	1.20	9.18
Mixed Commercial	1758	0.03	2.27	5.94	1.12	9.35

Notably, local schools and higher education buildings show quite different preferences, and highlight the differences in behavior seen across building sectors. Local schools exhibit below-average signaling preferences on aggregate (<9%), with more certifications coming from the Certified or Silver tiers. In contrast, higher education buildings are more likely to be motivated by signaling at the Gold and Platinum tiers.

4.8.2 Variation over Time

Table 3 displays changes in excess signaling motivations over time. For the full sample, the relative aggregate signaling preferences fall erratically over time, from 17.1% at the start to 10.3% when the most current observations are included. Declines in signaling motivation are consistent with the type of learning required in the RTT. This trend is reflected within the Certified, Silver, and Gold certification levels, but partially offset by increases in Platinum signaling.

Table 3 also shows these trends for subsamples based on owner types. These results highlight a stronger trend of decreased marketing in the for-profit subsample than in the government and non-profit subsamples. The government and non-profit subsamples decrease marketing over time somewhat, but this trend is more pronounced for for-profit buildings, where it is evident across all certification levels (with the exception of Platinum). Just over 18.25% of for-profit buildings revealed preference for signaling from 2000 – 2004, decreasing to 10.13% in the 2000-2013 sample. This result demonstrates that while the government and non-profit sectors have been consistently motivated by signaling, the for-profit sector began especially motivated by signals. But, as more certified, firms increasingly certified for the environmental performance benefits of certification. By 2013, the average for-profit building was slightly less likely to be a “signaler” than the average non-profit or government building. This is consistent with the assertion that a Race is dependent on traditionally competitive markets.

Table 4.3. Signalling Preferences over Time. Percentage represents excess share of certified buildings motivated primarily by signaling benefits, compared to a counterfactual uniquely constructed for each time period.

	Aggregate Revealed Preference for Signaling -- All Buildings						Aggregate Revealed Preference for Signaling -- Gov.					
Time Period	Size	Certified	Silver	Gold	Platinum	Net	Size	Certified	Silver	Gold	Platinum	Net
2000-2004	101	2.84	4.75	9.49	0.00	17.07	37	1.79	5.37	9.38	0.00	16.54
2000-2005	208	2.34	6.14	9.79	0.00	18.26	81	1.57	6.52	10.05	0.00	18.14
2000-2006	350	0.72	6.99	9.63	0.00	17.34	136	0.62	7.65	9.09	0.00	17.36
2000-2007	560	0.21	5.58	6.50	0.64	12.93	211	0.19	5.41	6.22	0.41	12.23
2000-2008	882	0.24	6.41	4.74	1.28	12.67	324	0.20	6.75	3.87	0.88	11.71
2000-2009	1481	0.37	3.33	6.57	0.59	10.86	525	0.36	3.79	5.91	0.55	10.61
2000-2010	2318	0.05	1.67	6.92	0.33	8.98	830	0.06	1.77	6.97	0.33	9.14
2000-2011	3064	0.12	2.32	6.42	2.54	11.39	1187	0.12	2.36	6.68	0.78	9.94
2000-2012	3504	0.07	2.52	6.85	2.98	12.41	1415	0.06	2.49	6.92	0.94	10.42
2000-2013	3675	0.08	2.67	6.64	0.89	10.28	1483	0.07	2.61	6.67	0.90	10.26

	Aggregate Revealed Preference for Signaling -- Firms						Aggregate Revealed Preference for Signaling -- NGO					
Time Period	Size	Certified	Silver	Gold	Platinum	Net	Size	Certified	Silver	Gold	Platinum	Net
2000-2004	45	3.92	4.45	9.88	0.00	18.25	19	2.32	4.24	8.78	0.00	15.34
2000-2005	85	2.74	7.25	10.11	0.00	20.10	42	3.03	3.14	8.62	0.00	14.79
2000-2006	129	0.77	7.26	9.26	0.00	17.30	85	0.81	5.51	11.05	0.00	17.37
2000-2007	216	0.21	5.74	6.41	0.18	12.54	133	0.23	5.59	7.11	1.74	14.67
2000-2008	340	0.25	5.91	4.86	0.84	11.86	219	0.27	6.68	5.79	2.53	15.28
2000-2009	594	0.37	2.88	6.82	0.35	10.42	366	0.38	3.34	7.05	1.02	11.80
2000-2010	920	0.05	1.64	6.53	0.23	8.45	578	0.05	1.56	7.02	0.50	9.13
2000-2011	1139	0.13	2.40	6.04	0.52	9.08	749	0.11	2.10	6.58	0.94	9.73
2000-2012	1245	0.07	2.66	6.65	0.70	10.08	856	0.06	2.33	7.00	1.14	10.53
2000-2013	1312	0.08	2.85	6.51	0.70	10.13	893	0.08	2.50	6.77	1.14	10.49

4.8.3 Robustness Checks

There are many potential forms of the counterfactual used for this analysis. In addition to the counterfactual and results presented above, we test a variety of alternative expectations. These may be derived theoretically, as done by Corbett and Muthulingam (2007), or a notches approach to empirically estimate the counterfactual. Results are robust for all smooth counterfactuals tested, due to the way signaling benefits that accrue discontinuously at certification thresholds, where the observed distribution peaks strongly. Though ARP values vary with methodological choices, the trends are consistent. Below we summarize results from one alternate form of the counterfactual.

As before, we construct an empirically-driven counterfactual using a notch approach. In the previous form of the counterfactual, this was executed by ignoring observations within two LEED points of a threshold, then constructing a second-degree locally-smooth polynomial across the remaining distribution, smoothing over a bandwidth of two. In the alternative counterfactual below (Figure 6), we continue to ignore this same window of observations, while smoothing with a first-degree (linear) polynomial, selecting a bandwidth of 4 points.

The result is that this counterfactual has less curvature compared to the previous form. When smoothing over the larger bandwidth, the polynomial becomes less sensitive to the steep peaks in the observed data, further smoothing the lumpiness of the observed distribution. This alternative form of the counterfactual is perhaps more consistent with priors about certification in the absence of tiers. However, the initial counterfactual demonstrates similar results without deviating so extremely from initial observation.

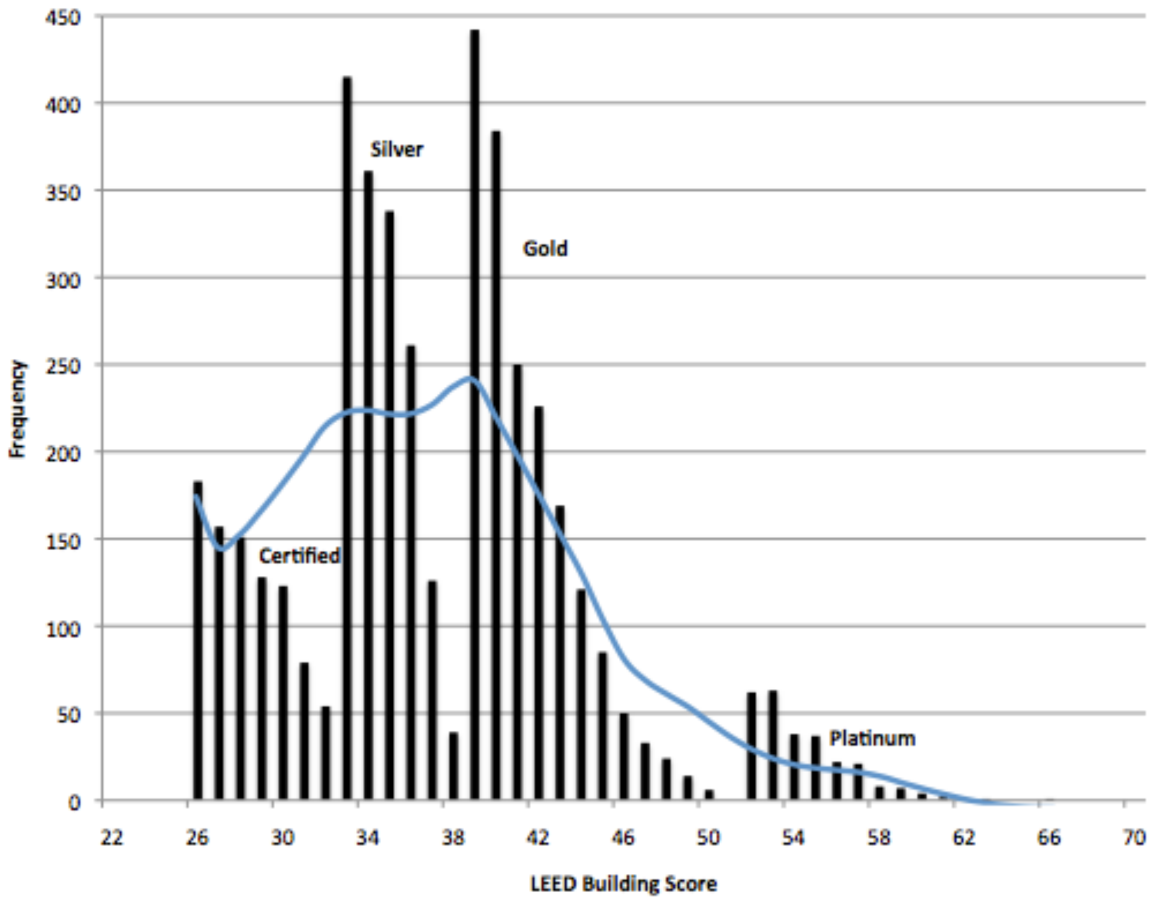

Figure 4.6. Observed Building Distribution Alongside One Alternative Counterfactual. Counterfactual distribution constructed with locally smoothed polynomial of degree 1.

The change in counterfactual calculation has implications for how we understand temporal shifts. Under this methodology, we exacerbate differences across thresholds, building categories, and time. Figure 7 displays how the counterfactual evolves over time. As before, the distribution of buildings shifts to higher thresholds, with fading peaks. The clarity with which the reader can observe the upward shift in the distribution from this counterfactual affirms the RTT: less marketing emphasis indicates less greenwashing.

Finally, we observe signaling preferences with this counterfactual calculation just as before. Cross sections of the whole sample are compared to reveal signaling preferences

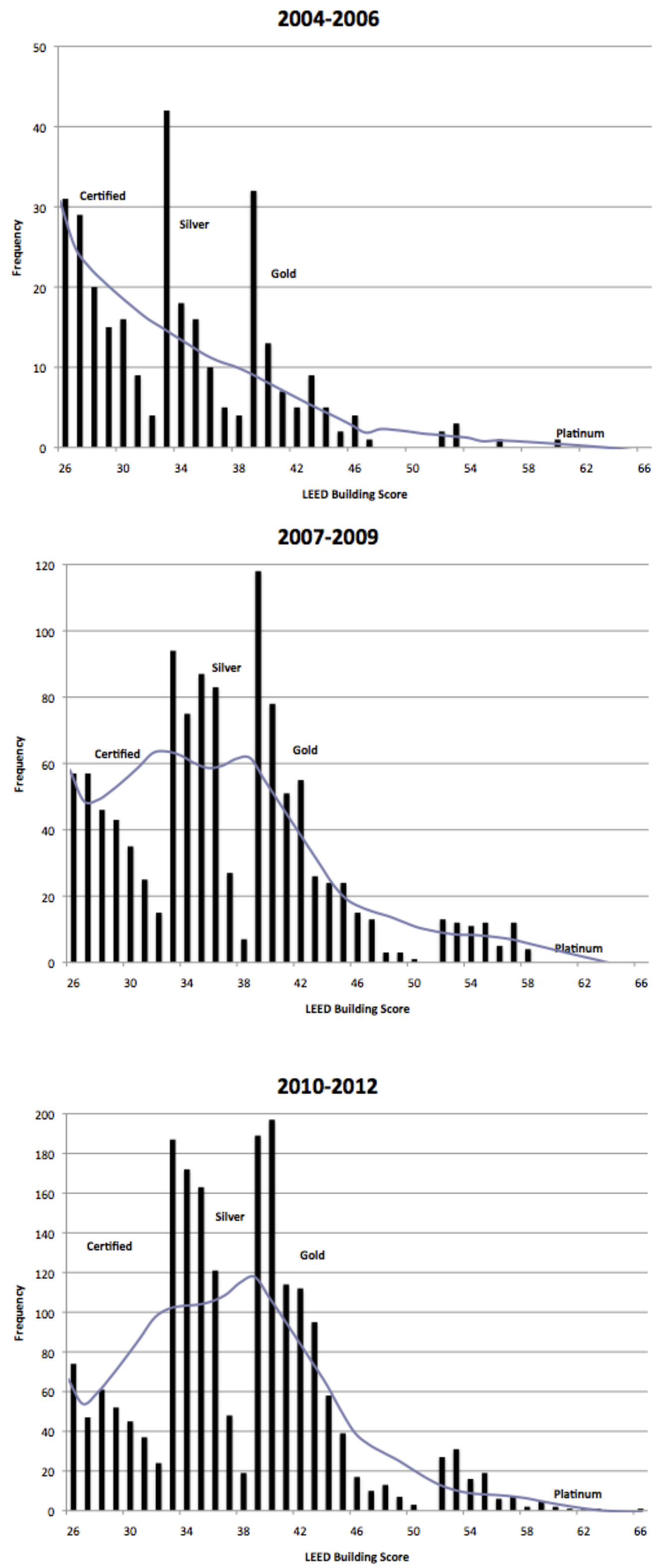

Figure 4.7. Changes in LEED NC Score Distribution over Time. This locally-smooth polynomial demonstrates near-unimodality at all points in time compared to the one previously addressed.

for each building category. These differences can be directly observed in Table 4. The counterfactual is also computed for each year T, including observations built in year $t \leq T$. The temporal trends are again observed in Table 5.

Note that results are again similar, with a few modifications. Because this version of the counterfactual rises less at observed peaks, the computed values for scheme orientation are larger for almost all LEED scores, suggesting a greater proportion of

Table 4.4. Signalling Motivations by Subsample Under the Alternative Counterfactual. Percentage represents excess share of certified buildings motivated primarily by signaling benefits.

		Aggregate Revealed Preference for Signaling				
Group	**Size**	**Certified**	**Silver**	**Gold**	**Platinum**	**Net**
All	4486	0.28	7.15	7.95	1.49	16.86
Federal or State Gov	1057	0.21	7.46	8.80	1.59	18.07
Local Gov	985	0.23	7.49	7.27	1.38	16.37
For-Profit	1445	0.32	6.83	7.75	1.14	16.04
Non-Profit	1018	0.32	6.92	7.97	2.01	17.22
Certified	870	1.42	0.00	0.00	0.00	1.42
Silver	1542	0.00	20.77	0.00	0.00	20.77
Gold	1806	0.00	0.00	19.74	0.00	19.74
Platinum	268	0.00	0.00	0.00	24.92	24.92
At Least Silver	3616	0.00	8.86	9.86	1.85	20.56
At Least Gold	2074	0.00	0.00	17.19	3.22	20.41
For-Profit Certified	340	1.33	0.00	0.00	0.00	1.33
For-Profit Silver	518	0.00	18.97	0.00	0.00	18.97
For-Profit Gold	523	0.00	0.00	21.42	0.00	21.42
For-Profit Platinum	64	0.00	0.00	0.00	25.79	25.79
Firm- At Least Silver	1105	0.00	8.89	10.14	1.49	20.52
Firm- At Least Gold	587	0.00	0.00	19.08	2.81	21.89
Higher Education	773	0.23	6.03	9.72	2.31	18.30
Local Schools	513	0.30	7.51	7.15	1.06	16.02
Health	268	0.40	7.79	8.69	0.55	17.42
Hotel	92	0.32	8.98	8.91	1.16	19.37
Restaurant	159	0.33	7.21	8.96	0.98	17.48
Retail	427	0.22	7.02	7.36	1.11	15.72
Office	1338	0.29	6.81	7.41	1.58	16.08
Mixed Commercial	1758	0.28	7.02	7.61	1.48	16.38

buildings certified for signaling gains. More interestingly, the relative value of signaling preference at the Silver threshold is larger in comparison to the Gold threshold for this form. Under the former counterfactual, almost all signaling preference was observed at the Gold level; under the present form, Silver and Gold comprise nearly equal shares, though Gold remains largest for almost all sectors and years.

4.9 Discussion and Concluding Remarks

We began from a seemingly simple question: *can a voluntary program induce a Race to the Top?* An answer to this question required a careful definition of the Race to the Top, in order to identify the way in which a non-regulatory approach might induce a Race of any kind. The origins of the theory draw on regulatory differentiation under interjurisdictional competition. Yet these do not appear particularly useful for drawing expectations around non-regulatory policy mechanisms. Worse, the theory has been repeatedly called to question by empirical studies refuting the Race. Despite the frequent theoretical and empirical critiques of the Race, it has remained an intriguing notion to scholars in many fields. To satisfy our collective curiosity, we consider an alternative approach the notion of a Race.

In place of the regulatory differentiation mechanism, we establish a set of conditions through which a Race might be established with an information mechanism. Noting that a Race need not occur if a market is at a socially optimal equilibrium, we deduce that the Race begins from market failure. Specifically, information asymmetries inhibit optimal consumer choice. By providing an information signal, firms face initial incentive to improve quality, gain experience in new practices, learn over time to implement those practices in more cost-effective ways, and make broader adoption more feasible, can produce a cycle of iterative

Table 4.5: Temporal Trends in Signalling for the Alternative Counterfactual. Percentage represents excess portion of buildings certified just above a threshold, compared to a counterfactual uniquely constructed for each time period.

	Aggregate Revealed Preference for Signaling -- All						Aggregate Revealed Preference for Signaling -- Gov.					
Time Period	Size	Certified	Silver	Gold	Platinum	Net	Size	Certified	Silver	Gold	Platinum	Net
2000-2004	101	3.39	9.31	10.51	0.00	23.21	30	2.63	11.44	12.34	0.00	26.42
2000-2005	208	2.80	11.10	8.19	0.00	22.09	75	1.99	11.76	9.47	0.00	23.22
2000-2006	350	1.06	9.61	8.57	0.00	19.24	128	0.97	10.69	8.61	0.00	20.27
2000-2007	560	0.74	6.78	5.53	0.46	13.51	198	0.78	7.17	5.68	0.26	13.89
2000-2008	882	0.69	6.88	5.58	0.92	14.07	308	0.68	7.63	4.82	0.64	13.78
2000-2009	1481	0.73	5.01	7.23	0.72	13.70	486	0.77	6.11	7.04	0.73	14.66
2000-2010	2318	0.45	5.33	7.25	0.74	13.76	765	0.53	6.13	7.84	0.81	15.31
2000-2011	3064	0.21	6.08	6.89	3.25	16.44	1097	0.22	6.75	7.71	1.25	15.93
2000-2012	3504	0.27	6.52	7.66	3.81	18.26	1306	0.26	7.35	8.34	1.44	17.40
2000-2013	3675	0.24	6.72	7.69	1.29	15.94	1367	0.24	7.55	8.33	1.42	17.54

	Aggregate Revealed Preference for Signaling -- Firms						Aggregate Revealed Preference for Signaling -- NGO					
Time Period	Size	Certified	Silver	Gold	Platinum	Net	Size	Certified	Silver	Gold	Platinum	Net
2000-2004	38	5.54	10.94	12.99	0.00	29.48	16	3.29	11.30	12.35	0.00	26.94
2000-2005	58	5.05	19.08	12.24	0.00	36.38	35	3.99	9.16	8.12	0.00	21.27
2000-2006	85	1.76	15.40	12.44	0.00	29.60	74	1.31	9.28	11.37	0.00	21.96
2000-2007	157	1.05	9.45	7.37	0.02	17.88	112	0.83	7.98	7.31	1.81	17.93
2000-2008	259	0.91	8.34	7.60	0.77	17.61	185	0.86	8.43	7.93	2.24	19.46
2000-2009	467	0.93	5.55	9.61	0.51	16.59	320	0.87	5.82	8.76	1.49	16.93
2000-2010	738	0.55	6.37	8.60	0.57	16.09	508	0.46	5.91	8.29	1.31	15.97
2000-2011	894	0.29	7.62	8.37	0.96	17.23	670	0.23	6.67	7.86	1.59	16.35
2000-2012	978	0.37	8.04	9.53	1.23	19.17	768	0.31	7.11	8.71	1.83	17.96
2000-2013	1031	0.32	8.31	9.66	1.26	19.54	807	0.27	7.36	8.67	1.86	18.16

improvement (Figure 1). This cascade effect has long been the hallmark of diffusion studies (Berry and Berry 2007), but has not been explicitly applied to a Race hypothesis. Diffusion studies are distinguished from the Race hypothesis based on how the adopted form of the practice evolves or remains stable over time.

Critically, this theory provides a mechanism by which a broad set of treatments and interventions may induce a Race. Though work on regulatory differentiation pertains only to command-and-control policy, modern policy designs increasingly draw on market- and information-based mechanisms, including voluntary programs. And, though regulatory differentiation as a mechanism is limited to competition among political jurisdictions, modern policymaking occurs through numerous non-state actors, such as from non-profits, interest groups, and industry coalitions. That these actors might introduce information that could induce a Race in local or global markets, even without political authority, is an important shift in our conceptualization of the notions of a Race to the Top, Race to the Bottom, or other market transformation. These are not purely regulatory outcomes, but rather emerge from correction of market failures that foster learning.

Further, the perspective we develop provides a functioning theory for the RTT and the RTB. That is, distinctive types of learning can incentivize adoption of a practice that has either more or less extensiveness and fidelity over time. Discussion here has focused on the RTT. Yet the RTB is expected under a slight variation from these same conditions. Absent enforcement, greenwashing, or adoption with diminished fidelity, can disrupt the RTT, and reward firms for overstating their environmental performance. We have termed this the weak form of the RTB. Alternatively, the strong form of the RTB expects both extensiveness and fidelity to diminish over time. That is, environmental performance worsens as a result of the information mechanism. This can occur, we argue, if organizations can learn to manipulate the information signals in their favor. This not only creates greenwashing, but also creates room for a sort of 'regulatory' gaming in which firms can influence the standard-setting process, curtailing future stringency (Maxwell, Lyon, and Hackett 2000).

Whether producing the RTB or the RTT, the learning perspective on Racing is contingent on a variety of assumptions. In addition to the assumptions stated explicitly in Table 1, a variety of contextual factors may inhibit the completion of the Race cycle. To name a few, the network structure may inhibit knowledge diffusion from those that have adopted to those who might adopt; other limitations of organizational capacity may inhibit learning from experience. Despite these potential limitations, data from LEED certified buildings are highly suggestive of a Race to the Top. Over time, LEED certification diffuses rapidly (Hypothesis 1), with greater portions of adopters choosing higher certification tiers, and higher LEED scores (Hypothesis 2). Across all subsamples, buildings generally certify just above the certification thresholds, demonstrating that building owners have invested additional resources to achieve a higher level of certification (Matisoff, Noonan, and Mazzolini 2014). Over time, we observe that builders are less likely to construct buildings that achieve a point total just above the threshold scores for certification, emphasizing performance gains over marketing benefits (Hypothesis 3).

Methodologically, we extend existing approaches that examine notches to identify distinctions in the signaling and performance motivations in a tiered setting. We anchor this measurement closely to the notion of fidelity and extensiveness in practice adoption, respectively. This allows us to construct meaningful measures of distributional shifts in the multitier framework, and examine evidence of a true Race to the Top. Without this distinction, it cannot be determined whether shifts are due to improved environmental performance, or simply to greenwashing. However, a multitier setting is not required for analysis of a Race per se. Information-based interventions take many forms, from which alternative operationalization of fidelity and extensiveness might be adopted.

Results suggest a RTT in the case of LEED certification, though the extent to which this phenomenon is generalizable is not particularly clear. If LEED is a singular phenomenon, we take little away from our analysis. An assessment of the LEED certification suggests affirms for program design more broadly. First, LEED is a certification, not simply a label that can be attached without substantive improvement. This enforcement mechanism imposes some costs to certification but appears effective in ensuring a stable signal of environmental quality. Second, that the USGBC actively cultivates network formation and learning through its AP trainings, its online platform for showcasing advances, and its connections with global actors with similar interests. The catalyst role that this network plays in maintaining the upward trajectory of the Race may be quite large. Third, the tiered structure provides slightly more information than a binary rating, yet may be concisely understood. And this structure provides incentive to reach a higher signal of environmental quality. That LEED frequently updates the certification standard to raise the bar for certification provides room for continuous growth.

With these design features, LEED appears effective at driving a RTT. This stands contrary to past expectations from the traditional Race to the Bottom literature, in which competition drives costly quality down over time. In fact, for-profit firms in the LEED data appear more susceptible to the RTT because of their competitive market context.

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CHAPTER 5: LEARNING OR LOCK-IN? THE EVOLUTION OF ENVIRONMENTAL MANAGEMENT PRACTICES

Voluntary and information-based policy approaches are increasingly popular tools for addressing environmental concerns, in part due to their flexibility, which is thought to prevent the technological lock-in resulting from more stringent regulatory approaches. But does the widespread adoption of a voluntary practice indicate its success? As practices of any kind spread, they are likely to evolve. This may be due to learning, by which organizations become more proficient at a practice as they gain collective experience, or may be due to late adopters seeking marketing gains by only symbolically adopting a practice. Voluntary programs that include monitoring to limit free-riding are thought to limit the latter, but empirical research is ambiguous about the persistence of environmental outcomes of these programs. To fill this gap, this paper investigates trends in the green building movement, which has spread widely in recent years. Green certified real estate that mitigates environmental footprints with regard to a number of concerns. Analysis of the dynamics of green technology choice reveal an increased emphasis on energy efficiency, but also suggest a diminished interest in providing public goods. These results suggests trade-offs between the flexibility and simplicity of a voluntary program.

5.1 Introduction

Investors in the real estate industry increasingly expect environmental certification when considering additions to their property portfolios (Eichholtz, Kok, and Yonder 2012). These programs, such as the tiered Leadership in Energy and Environmental Design

(LEED) certification, verify improvements to a building's holistic environmental footprint (Matisoff, Noonan, and Flowers 2016). In recent years, buildings have certified LEED in greater numbers (Kok and Holtermans 2014a, Kok, McGraw, and Quigley 2011), at higher certification tiers (Chapter 4), and overall appear to be increasingly sustainable. This may be the result of policies promoting green building (Matisoff, Noonan, and Flowers 2016), learning (Chapter 4), the potential operations savings of efficient building design (Asensio and Delmas 2017), and/or the promise of premium market returns to green certification (Eichholtz, Kok, and Quigley 2010a) as a signal of quality.

Such successively greener management appears to challenge past work suggesting that adoption becomes increasingly symbolic as a practice diffuses (DiMaggio and Powell 1983, Kennedy and Fiss 2009). Symbolic management may be the result of a variety of institutional pressures (DiMaggio and Powell 1983) to adopt, even when the "fit," or the extent to which the certification and adopter are aligned in terms of demands and goals (Nadler and Tushman 1980) is dynamic (Zajac, Kraatz, and Bresser 2000). Though this literature generally acknowledges that practices diffuse, the models do not anticipate incrementally more substantive practices over time.

But is environmental management actually improving environmental performance? Many have noted positive improvements, others note no or negative effects (Koehler 2007), while still others note diminishing environmental effectiveness of program adoption (Delmas and Montes-Sancho 2010, Toffel 2006). In the real estate industry, much disagreement exists over the extent to which green buildings save energy and avert emissions (Kats 2003), though recent work draws on advanced matching to identify significant efficiency improvements in certified real estate (Asensio and Delmas 2017). However, sustainability is a complex goal, relating to numerous practices and outcomes.

Though market interventions and public policies often promote multifaceted aims like sustainability, innovation, and health, such complexity renders progress difficult to assess (Stavins 1998). These constructs may be operationalized in numerous ways. In lieu of succinct observable outcomes, we often construct compound indexes of performance and observe changes in aggregate. For example, sustainability indexes have been tracked by the Dow Jones, the Earth Science Information Network, and portions of the KLD scores, with no clear best method. In order to understand what changes mean for progress toward a goal, we must open the black box of opaque indexes (Wijen 2014).

For environmental performance, this potentially means considering all possible approaches to addressing all possible externalities – a daunting task. Following Ansari, Fiss, and Zajac (2010), we may reduce our approach to understand the adaptation of practices in two dimensions, fidelity and extensiveness. This literature points to several propositions anticipating the dynamic relationship between loss of "fit" and reduced fidelity or extensiveness. The following draws on data from LEED building certification pathways over time, demonstrating how these shifts manifest, despite competing expectations. The certification system is first introduced before analysis is presented. The discussion emphasizes lessons for policy design.

5.2 The Case of LEED

As a voluntary certification program, LEED was created by a private organization to improve the design and environmental impact of the building sector, and to promote corporate social responsibility. The program works by verifying sets of improvements across a flexible menu of options; those who demonstrate sufficient sustainability become LEED Certified, and can become LEED Silver, Gold, or Platinum if they can prove even greater sustainable practices. Builders can earn "credits" for improvements to dozens of characteristics, impacting the near and long-term energy, water, land use, air quality, and natural resource footprint of the edifice. Though many of these technologies, like energy efficiency, offer cost-saving potential, others do not. Those which do not reduce cost are all associated with some type of public benefit, in line with an explicit aim of the LEED platform to provide public goods.

This multifaceted approach creates noisy quality signals, in which different builders certify through very different types of changes to the environmental impact. This noise may be understood as the result of two non-orthogonal dimensions (Chapter 3). First, the *fidelity* with which builders replicate existing norms may be observed by the extent to which they deviate from the general rule for assuring certification, surpassing requirements by scoring two or three points above the requirement. If they obtain far more than this, the certification under-represents the building's quality, in a brownwash. If they obtain less, the certification over-states quality compared to others with the certification, in a greenwash.

The degree of disclosure exacerbates differences in the second dimension: *extensiveness* of adoption differentiates the types of observable building characteristics that justify the quality signal. Those seeking certification can adopt practices that mostly benefit their bottom line, such as energy and water efficiency. Though efficiency is certainly beneficial, it strays from the aim of producing public benefits. That is, the externality of energy use is only indirectly related to the externalities of energy production, and so provides highly variable public benefits, with much clearer returns due to averted utility expenditures. That LEED buildings can vary in both fidelity and extensiveness creates a noisy signal of quality (Chapter 1).

5.3 Opening the "Black Box" of Certification Pathways

Despite some expectation that quality would diminish under signal noise (Stiglitz 2000), LEED appears to foster learning in the buildings industry, such that more become certified, LEED tiers and scores increase, and marketing seems a less important driver of this trend (Chapter 4). Presumably, these higher scores mean greater benefits to the public (as the probability of adopting any particular LEED credit strictly increases as more of the available credits are adopted). Yet the marginal credit earned toward certification is often related to private gains, such as energy efficiency, rather than public gains (Chapter 2). This seems to suggest that certification fills some of the energy efficiency gap by addressing some market failures, but fails to provide public goods. On the other hand, the signaling benefits of LEED tiers appear to become less important over time (Chapter 4). So, the practice of leveraging added efficiency to pass from one tier to the next may not undermine the program's aim of promoting corporate social responsibility and public goods.

Our understanding of LEED as a program that has induced improved environmental outcomes over time relies on two assumptions. First, that the technologies conferring private benefits have been properly identified; and second, that LEED scores directly relate to public good provision. The former can be identified in engineering studies or can be observed anecdotally. The latter requires analysis of the certification pathways. To know whether progress has been made to incentivize public good provision under the LEED label, data from certifications throughout the lifespan of a LEED label may be observed.

Expectations regarding this evolution may be drawn from a variety of perspectives. First, signaling theory anticipates noisier signals, with greater emphasis on marketing benefits among late adopters hoping to free-ride on premiums (Stiglitz 2000, Potoski and Prakash 2009). This would be observable as the increase in quality variation (more mixing of public and private goods), and as the increased focus on marketing benefits, or even greenwashing. On the other hand, the organizations literature suggests that late adopters will certify less extensively (Ansari, Fiss, and Zajac 2010), more symbolically (DiMaggio and Powell 1983), or by focusing more on avoiding losses than pursuing gains (Kennedy and Fiss 2009). These expectations all suggest greater emphasis on efficiency and private benefits, rather than public good provision.

Alternative perspectives suggest related, but distinct hypothesis. Learning suggests that, as organizations become more proficient at certifying through the least-cost means, certification pathways will focus increasingly on technologies with rapidly falling costs (Spence 1981). In this case, convergence occurs as collective experience and innovation reveal cost-minimizing pathways. Convergence may also be the result of institutional pressures to adopt, which can foster the use of "off the shelf" (conforming) design, rather than tailored (customized) design (Westphal, Gulati, and Shortell 1997). Alternatively, certification may be adopted in response to emerging problems and dialogues (Kingdon 1984). This suggests that, as public attention shifts to address new environmental concerns, such as habitat and species loss, climate change, or indoor air pollutants, certification

Table 5.1. Qualitative Credits and How They Relate to Each Theory.

Certification Pathway	Description	LEED Credits
Private Benefits	Provides Return on Investment (ROI) based on efficiency	*Energy Efficiency, Onsite Renewable Energy, Enhanced Commissioning, Water Use Reduction*
Occupant Benefits	Promotes productivity through enhanced indoor quality	*Alternative Transportation (Public Transit Access, Bike Storage, EV Parking, Parking Capacity, Development Density and Walkability), Green Roof Spaces (Rooftop Heat Island Mitigation), Indoor Quality (Outdoor Air Monitoring, Increased Ventilation, Low Emitting Materials, Reduced Indoor Chemicals, Thermal Controls and Comfort, Daylighting, Views of the Outdoors)*
Construction Site Pollution Reduction	Reduces worker exposure or pollutant runoff	*Construction Waste Management, Construction Air Quality, Low Emitting Materials*
Increased Accessibility	Increased demand or popularity lowers cost or increased availability	*Energy Efficiency, Onsite Renewable Energy, Green Power Purchasing, Water Efficiency, Construction Waste Management, Recycled Materials, Low Emitting Indoor Materials, LEED Accredited Professionals*
Ad hoc Changes	Can be purchased and added, without advance design	*Recycled Materials, Local Materials, Renewable Materials, Certified Wood, Green Power Purchasing, Low Emitting Indoor Materials*
Visible Changes	Can be observed without certification	*Bike storage, EV parking, Rooftop Heat Island Mitigation, On-site Renewable Energy, Water Efficient Landscaping, Daylighting, Views of the Outdoors*
Public & Biodiversity Benefits	Preserves environmental quality through habitat and land preservation	*Brownfield Redevelopment, Habitat Protection, Maximize Open Space, Light Pollution Reduction, Certified Wood*

would increasingly assuage those concerns. From above, we can infer that convergence in certification pathways ought occur, with late adopters showing less variation in the technologies selected toward certification.

Hypothesis 1: Over time, certification pathways converge, showing less customization.

Each of the assertions in Table 1 provides expectations about specific shifts in the types of technologies adopted for certification under the flexible LEED program. Distinguishing how certification pathways evolve requires observation of the technologies adopted for certification with analysis for trends over time. Past work has established differences in technologies adopted across market sectors and in pursuit of higher certification (Chapter 1). In the following, trends over time are assessed. To make sense of so much variation in technologies within the noisy certification framework, groups of environmental practices for which builders earn "credit" toward LEED certification are identified in terms of their relationship to each of the presented theories. In particular, the adaptation of LEED certification that provides public goods versus private gains is examined. Along the way, various other trends are noted. The environmental practices expected to emerge from the evolution of LEED certification under each perspective is summarized qualitatively in Table 1.

By opening the "black box" of certification, we treat each practice as a separate quality, complicating analysis by introducing dozens of outcome variables. Yet, this high-resolution approach also offers a unique opportunity to differentiate competing and complementary expectations about the emergent form of certification. That is, many theories can be asserted to explain any one trend, but few will jointly provide consistent explanations for trends along all characteristics embedded in the analysis (Stinchcombe 1987). To preserve the power of this testing while minimizing the family-wise error rate (FWER), we can reassess trends with Bonferroni-corrected p-values (Bonferroni 1935, 1936). More simply, we can collect individual characteristics along dimensions of interest from Table 1, reducing the number of tests conducted.

Analysis begins from expectations about learning. Consistent with psychological depictions of learning, Arrow (1962) described technical changes as related to accumulated experience in production that drive reduced labor costs. Conley (1970) extends this conceptualization to include all costs, measuring overall experience. Learning curves, which depict the exponential drop in costs as scale increases, have become a powerful tool for describing dynamic technology preferences (Williams and Tarzian 1993, Grubler, Nakicenovic, and Victor 1999). Because economic theory anticipates rational cost-minimization in technology choice, the increased use, or diffusion, of emerging technology is expected under cost reductions and competition (Spence 1981).

Hypothesis 2. Over time, certification pathways converge on reduced-cost technologies.

However, not all increases in production or diffusion correspond to cost reductions (Yelle 1979), and not all cost reductions correspond to increased adoption (Lieberman 1989). For example, Nemet (2006) describes organizational and market structures as key inhibitors of learning. From literature on institutional isomorphism, we observe a complimentary perspective that links the form of compliance to the motivations to comply. As a mechanism by which social and cultural influences impact strategic decision-making (Ingram and Silverman 2002), this body of literature broadly suggests that conformity to dominant practices confers legitimacy to those adopting (DiMaggio and Powell 1983). Pursuing legitimacy, firms need only adopt practices symbolically (Meyer and Rowan 1977), with or without tangible evidence of change. Pressures from regulatory agencies or competing firms may accelerate the decoupling of formal structures and actual practice

(DiMaggio and Powell 1983), as late adopters minimize losses rather than pursue technical gains (Kennedy and Fiss 2009).

Institutional pressures to adopt sustainable practices arise from several stakeholders in the building sector. Adoption may be the result of market or public relations pressures (Braithwaite 1989, Henriques and Sardorsky 1996). Notably, late adopters with low-quality products may have less substantial environmental improvements, while still earning the premium commanded by leader firms in their industry (Delmas and Montes-Sancho 2010), or at least diminishing the willingness to pay for the label. In this sense, decoupling makes room for a form of greenwash (Lyon and Montgomery 2015), in which organizations mislead stakeholders by being green in name only. In the case of certification, where monitoring and enforcement ensure quality improvements, this implies a deviation from the original aims of the program, or a reduction in fit (Ansari, Fiss, and Zajac 2010). For LEED certification, this may manifest as a focus on private benefits, rather than the provision of public goods related to sustainability.

Hypothesis 3. Over time, pathways converge on technologies conferring private gains.

Hypotheses 2 and 3 are often closely related. For example, recent advances in numerous energy technologies have reduced the costs of energy production and energy efficiency, and implementing these technologies reduces long-run operating costs. However, not all technologies have characteristics of both: some have become more accessible and affordable but do not offer private gains, others offer private gains but may not have changed dramatically in cost (Table 1). Though both hypotheses may be upheld, this is not required for interpretation of the observed trends.

Table 5.2. Contingent Interpretation of Hypotheses regarding the evolution of certification pathways over time.

Pathway Convergence	Related Hypotheses	Interpretation
Reduced-Cost Technologies	H1, H2	*Learning drives the adaptation of certification pathways, despite expectations for symbolic management. The fit between the program and its adoption remains high.*
Reduced-Cost Technologies, and Technologies Conferring Private Gains	H1, H2, H3	*A combination of learning and symbolic management drives the adaptation of certification pathways.*
Technologies Conferring Private Gains	H1, H3	*Symbolic management drives the adaptation of certification pathways, as the fit between the program and its adoption erodes in some fashion. This occurs despite expectations that learning should enhance performance.*
Neither Technology Types, or No Convergence	(H1)	*Certification pathways are either highly tailored, or a not strategically selected.*

Importantly, if evidence suggests that Hypothesis 2 is upheld, but not Hypothesis 3, we can understand that learning occurs and allows tailored approaches to certification that minimize costs while remaining consistent with the programmatic aims of LEED certification. On the other hand, if Hypothesis 3 is upheld, but not Hypothesis 2, evidence would suggest that a lock-in effect occurs, in which organizations adopt technologies without cost-minimization. These distinctions are surmised in Table 2. To differentiate between these two hypotheses requires tests that distinguish between the emergent characteristics, while controlling for related trends in the market for green buildings.

Data on LEED pathways for 2,981 buildings under the New Construction version 2.2 certification system were made available for this study. The data span ten years of registrations, from 2004 to 2013, with final certifications running through 2014. This rating system was selected among other, similar rating systems for other types of buildings due to its large market uptake. Additionally, the properties are mostly owner-occupied, rather than leased. Half of owners are government agencies; for-profit and non-profit organizations each make up about seventeen percent of the data, and mixed ownership or public-private partnerships sponsor the remaining portion of buildings observed. Because certification includes parameters from site selection through construction and occupancy, more control may be exerted over the certification pathway of a newly constructed buildings, compared to renovations.

This is the first version of LEED for which complete data are available, including owner information (name, sector), building use, certification information (date of registration and certification, certification tier and score, as well as complete qualitative data on each LEED credit obtained toward certification), and location (including coordinates, address, an ordinal measure of development density, and climate zone). Development density is measured from one (dense metropolitan) to seven (very rural). Location information is missing for a few hundred confidentially certified buildings. Later analysis is conducted with and without location controls, dropping observations with missing data as necessary.

5.4 Convergence of Certification Pathways

The diversity of certification pathways used under the LEED label creates a novel arena in which to test and apply theories describing the evolution of practices under opaque regulatory regimes, and the emergence of a dominant form of a particular practice. Based on hypotheses elaborated above, LEED certification pathways are expected to be more homogenous over time, and to increasingly rely on pathways that minimize costs and/or confer private benefits. Hypothesis testing begins by constructing indexes of diversity. These test whether early adopters customize certification pathways more than latecomers. Then, trends over time are examined for each of the credits available, in order to gain a broad perspective on how technology choices evolve in pursuit of certification. Regression models are used to examine evidence in a multivariate setting, controlling for various other factors that may influence how organizations certify. Finally, several approaches are used to depict market sector differences in certification behaviors.

The first hypothesis anticipates declining variance in the paths used towards LEED certification. Homogeneity in certification pathways may be measured using several indexes. Generalized variance, sometimes referred to as the Blau index (1970), of categorical variables is here used, and compared with results from similar indexes for robustness. Alternate measures include polarization and entropy. Generalized variance and entropy increase with diversity within groups, and decrease with homogeneity. Patterns for polarization follow the inverse pattern, increasing with homogeneity (Solanas et al. 2012). To apply this tool, each buildings' certification pathway is identified as the total set of credits obtained, such that identical pathways can be readily noted as identical sets. The range of unique pathways in use becomes a set of categorical variables. Certification dates serve to group buildings into monthly cohorts, and diversity indexes are measured for each cohort. These indices, measures of pathway variance, are plotted over time.

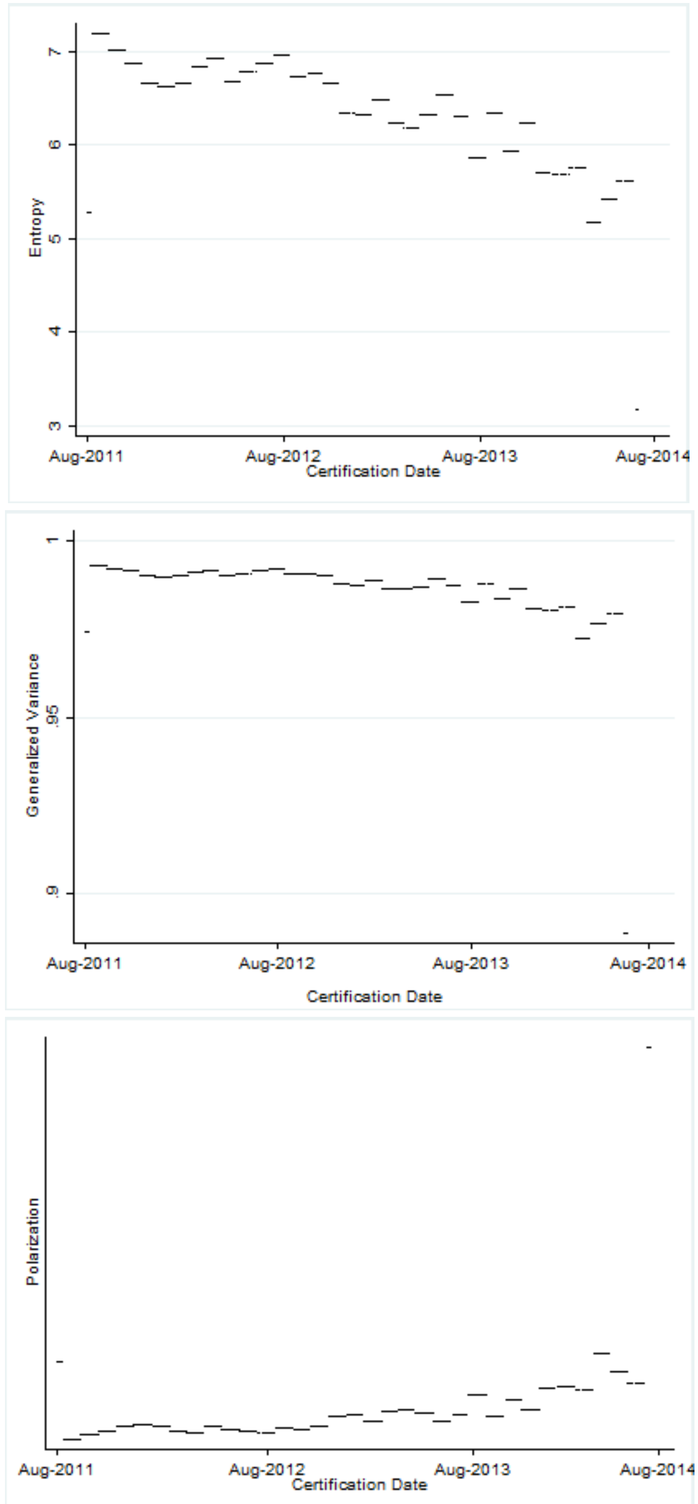

Figure 5.1. Certification Pathway Diversity Decreases over Time. On these graphs, entropy is an index of diversity, like the Generalized Variance (Blau) index. Polarization measures homogeneity.

As observed in Figure 1, pathway variance decreases across months. This effect is most pronounced in the entropy index, but each index generally affirms Hypothesis 1. Note that the bookend months of this graph contain only about two weeks of data, reducing the frequency of observations and lowering the potential diversity (Solanas et al. 2012). Even with these outliers, the trend still clearly suggests increased conformity. As measured, diversity appears quite high, even among late adopters. This is partially due to the high degree of freedom in certification options, which vary in both tier and type of credits.

5.5 Identifying the Dominant Certification Pathway

The choice of green technologies towards certification is, as introduced above, far from universal, and still evolving. As LEED certification becomes more popular, and as the program gains traction in new geographic regions and building market sectors, shifts in popular credits may occur for a variety of reasons. Data are observed in terms of the particular credits chosen over time. For each credit in the scoring system, correlations between the likelihood of adoption and adoption timing are calculated. Here, and throughout analysis, time is operationalized as the lag between a project's certification date and the date of the first project certified in the data.

Statistically significant correlations between time and credit adoption may provide insight about drivers of trends observed. Table 3 presents these correlations, using Bonferroni-adjusted p-values. LEED scores and certification tiers tend to increase throughout the period of observation. Increasingly, pathways rely on credits from the Energy and Atmosphere category. This is mostly based on increasing adoption of credits associated with energy efficiency (Optimize Energy Performance, and Enhanced

Table 5.3. Correlations between LEED building characteristics and certification timing.

LEED Project Characteristics: Correlation with Certification Timing

Project Certification Stats		**Energy & Atmosphere**	**0.060*****	**Environmental Quality**	**-0.014**
Certification Tier Awarded	0.035*	Optimized Energy Performance	0.044**	Outdoor Air Delivery Monitoring	0.023
LEED Score	0.036**	On-Site Renewable Energy	0.071***	Increased Ventilation	0.002
		Enhanced Commissioning	0.054***	Construction Air Quality 1	0.042 **
Sustainable Site Selection	**0.017**	Refrigerant Management	0.029	Construction Air Quality 2	-0.008
Site Selection	0.002	Measurement & Verification	0.002	Low Emitting Materials (adhesive)	-0.001
Development Density	0.015	Green Power Purchasing	-0.029	Low Emitting Materials (paint)	-0.006
Brownfield Redevelopment	0.028			Low Emitting Materials (carpet)	-0.035 *
Public Transit Access	0.010	**Materials & Resources**	**0.004**	Low Emitting Materials (composite)	-0.027
Bike Storage	-0.053***	Building Reuse, Level 1	-0.011	Indoor Chemical Controls	0.031 *
Low Emission Vehicle Parking	-0.026	Building Reuse, Level 2	-0.013	Lighting Controls	0.001
Parking Capacity	0.010	Building Reuse, interiors	-0.008	Thermal Controls	0.010
Habitat Protection	-0.015	Construction Waste, Level 1	0.017	Thermal Comfort Design	0.013
Maximize Open Space	0.027	Construction Waste, Level 2	0.033*	Thermal Comfort Verification	-0.009
Stormwater Quantity Control	0.031*	Materials Reuse, Level 1	-0.012	Day lighting	-0.067 ***
Stormwater Quality Control	0.028	Materials Reuse, Level 2	-0.012	Views	-0.032 *
Non-roof Heat Island Mitigation	0.051***	Recycled Content	0.030		
Rooftop Heat Island Mitigation	0.028	Regionally Sourced Materials 1	0.014	**Water Efficiency**	**0.025**
Light Pollution Reduction	-0.065***	Regionally Sourced Materials 2	0.008	Efficient Landscaping, Level 1	0.016
		Rapidly Renewable Materials	-0.024	Efficient Landscaping, Level 2	0.013
Innovation	**-0.020**	Certified Wood	-0.046**	Innovative Wastewater Technology	-0.012
Innovation & Design	-0.021			Water Use Reduction, Level 1	0.039 **
LEED Accredited Professional	0.022			Water Use Reduction, Level 2	0.034 *

Significance at the 0.1, 0.05, and 0.01 levels are marked with *, **, and ***, respectively.

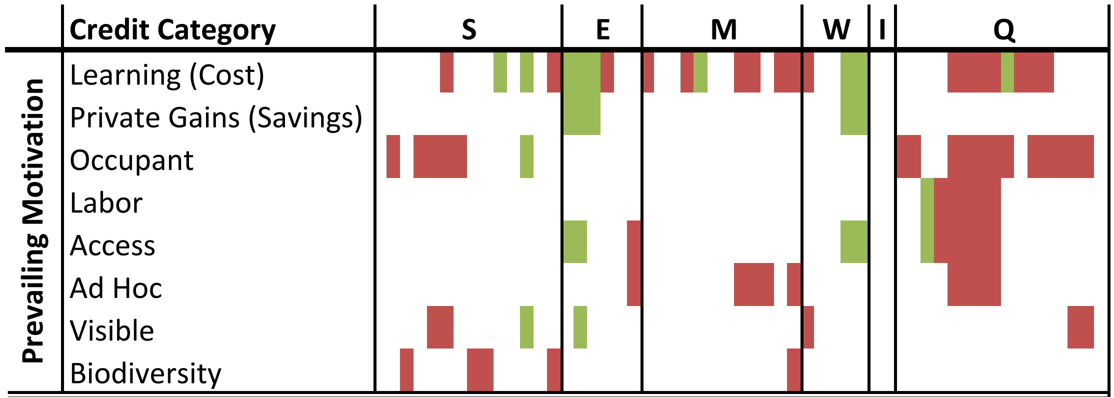

Figure 5.2. Visualization of LEED Certification Pathway Trends compared to prevailing motivations to certify. Potential motivations from Table 1 are list row-wise, and each LEED credit across the columns. (The dozens of LEED credits are grouped into credits pertaining to Site selection, Energy, Materials, Water, Innovation, and Quality of indoor environments). White space indicates no changes anticipated for that combination of credit and motivation. Green spaces note where expectations are upheld; and red marks refuted expectations.

Commissioning), and renewable energy production. Notably, onsite renewable power increases, but renewable power purchasing from the grid decreases.

Water efficiency (Water Use Reduction) and also increases over time, along with credits for stormwater, heat island, construction waste, construction air quality, and indoor chemical management. By comparison, credits that appear less popular over time include bike storage, light pollution reduction, innovation, use of certified forestry products, low-emitting materials, daylighting, and views of the outdoors. Other credits in the scoring system show no significant changes over time.

Assessing practice adaptation trends in Table 3 to the sets of credits listed in Table 1 provide initial insights into how decisions about certification pathways are made. To do this, Figure 2 visualizes relationships between expected practice adaptations and observed trends. Here, each credit in the LEED scoring system occupies a narrow column of space, with groups of credits corresponding to environmental impacts labeled across the top.

Rows provide room for differing expectations about credit adoption over time. A single logic for shifts in credit adoption occupies each row. White space within the resulting matrix indicates no expectations, while filled spaces mark red and green for refuted and upheld predictions. That is, the prevalence of red-shaded space in Figure 2 reveals that most of these expectations are not upheld, or are only partially upheld.

Over time, LEED credits that confer public and biodiversity benefits do not significantly increase in popularity, and, more pointedly, the use of certified wood and light pollution mitigation technology decreases. Of the visible changes that could be used for conspicuous conservation, bike storage, and the large windows required for daylighting and outdoor views credits become much less common. The use of renewable energy becomes more common, but this credit is grouped in multiple categories. Technologies that may be ad hoc purchased and installed with little planning for LEED credit, including green power purchasing and indoor materials, show no increases or even show decreases in popularity. The same may be said of credits that confer benefits to occupants through improved indoor environmental health, or to construction workers through mitigated workplace air pollution.

If learning occurs, it is not driving uptake of technologies offering these benefits. In fact, it is evident from Figure 2 that the only motivation offers a set of expectations that is logically consistent with observed trends is the expectation that private gains will be increasingly favored, regardless of decreasing technology costs. Though these credits occupy a small portion of the visualization, but account for more than a quarter of the points possible in the final LEED score. Still, observed trends in correlation tables may be partially or fully explained by the diffusion of LEED to new market sectors or new geographic regions. Therefore, a multivariate approach is needed to test for increased pathway reliance on cost-minimizing technologies.

5.6 Multivariate Analysis

I model adoption of each of the credits associated with falling upfront costs or long-run private benefits from efficiency as a function of time and a binary indicator of private-sector ownership. The models control for a set of variables related to overall score, building location, and building use, which might explain some of the variance in credit preferences. Some building attributes may be in vogue among urban peers, promoting adoption within rapidly developing cities. Moreover, some strategies may be more feasible or available in rural versus urban areas. Location is controlled with respect to development density, using an ordinal measure ranking areas from high to low density. In addition, regional variance exists in energy demand (which changes with heat and humidity), natural resources (such as incident solar), and water restrictions (which increases salience of conservation and runoff). Fixed effects for climate zones are included to control for this variation. Finally, buildings constructed for different uses may have very different design needs. A set of dummy variables are included, controlling for building uses ranging from schools, homes, factories, civic spaces, offices, stores, hospitals, and hotels.

Multivariate models in Table 4 confirm that trends are not purely the result of LEED diffusing to new regions or building market sectors. After controlling for location, building use, and market sector, private benefits remain the dominant strategy for certification over time. Notably, the use of these strategies does not appear to be differentiated by owner type, as for-profit owners are significantly less likely to pursue

Table 5.4. Multivariate Regression Models depicting credit adoption for technologies providing private benefits. Panel (a) depicts adoption models for individual credits using logistic regression, while (b) depicts ordinary least-squared regression models for aggregate credit groupings. Interaction terms are included in panel b.

(a) Logistic Regression	*On-Site Renewable Energy*	*Enhanced Commissioning*	*Water Use Reduction: Level 1*	*Water Use Reduction: Level 2*
Time	0.0071***	0.00508***	0.00747	0.0024
	(0.00023)	(0.00017)	(0.00047)	(.00028)
For-Profit Owner	0.23600	-0.254*	0.0739	-0.353*
	(0.191)	(0.141)	(0.329)	(0.200)
LEED Score	0.20500***	0.144***	0.176***	0.109***
	(0.012)	(0.0097)	(0.0266)	(0.0146)
Development Density	0.06320	-0.0513	0.0302	0.0312
	(0.0469)	(0.0351)	(0.0979)	(0.0568)
Climate Zone Fixed Effects	*yes*	*yes*	*yes*	*yes*
Building Use Fixed Effects	*yes*	*yes*	*yes*	*yes*
Constant	-9.12000***	-5.946***	-2.482	-0.55
Observations	2,361	2,367	2,361	2,361

	Optimize Energy Performance		All Efficiency Credits	
(b) OLS Coefficient	*(1)*	*(2)*	*(3)*	*(4)*
Time	0.0037**	0.0012	0.0076***	0.0054***
	(.00016)	(.00018)	(.00019)	(.00021)
For-Profit Owner	0.17300	0.22300	0.29500	0.53400**
	(.19)	(.221)	(.22)	(.26)
For-Profit Owner x Time	-0.00083**	-0.00018	-0.00139***	-0.00092*
	(.00038)	(.00043)	(.00043)	(.00049)
LEED Score	0.23800***	0.23800***	0.35000***	0.34600***
	(.00506)	(.00608)	(.00638)	(.00768)
Development Density		0.19700***		0.21400***
		(.0332)		(.0387)
Climate Zone Fixed Effects	*no*	*yes*	*no*	*yes*
Building Use Fixed Effects	*no*	*yes*	*no*	*yes*
Constant	-3.92400***	-4.15700***	-5.50200***	-5.51100***
Observations	2981	2367	2981	2367
R-squared	0.33500	0.36100	0.45000	0.46100

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

efficiency credits, and no significant relationship exists between owner type and the other certification strategies depicted. Inclusion of owner type as an interaction term (Table 4b), or running these regressions as hazard models (Figure 3) does not clearly differentiate trends for public and private owners.

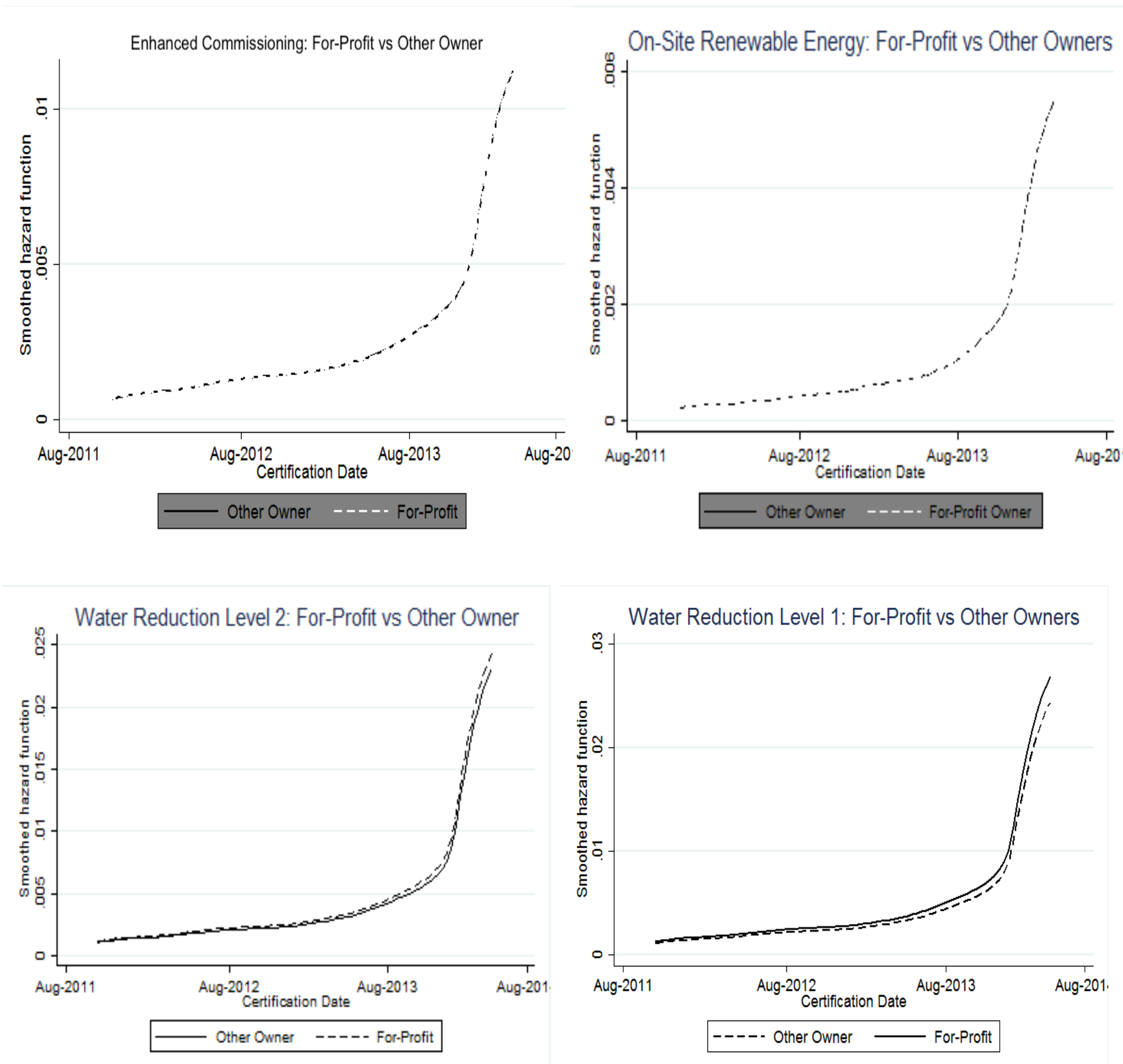

Figure 5.3. Cox Proportional Hazard Models show differences in certification pathways for for-profit vs other owners. Fixed effects included for building use and climate zone.

An alternative specification draws on the Cox proportional hazard model, which uses maximum likelihood estimation to estimate the "risk" of adopting a LEED credit over time. While no assumptions are made about the baseline hazard, but does presume that the two market strata (public and private owners) face constant relative hazards (Cox 1972). That owners facing very different market conditions adopt indifferentiable certification pathways could challenge this assumption, or simply suggests that architects influence pathway determination, specializing in building types that cut across ownership sectors. If the latter, conformity may be accelerated. Of note in Figure 3 is the sharp upward bend in the likelihood of adopting most LEED practices in the Autumn of 2013. In this year, an updated version 4 of the LEED certification program was introduced, suggesting that those still using version 2.2 are the tail end of adopters.

5.7 Improved Technological Fit?

The data presented above suggest an increased emphasis on certification pathways that provide private benefits to the building owner through energy and water efficiency. Standardization of certification pathways increases uniformity of quality across those adopting, in an apparent reduction of signal noise. This challenges economic perspectives anticipating increasingly noisy signals from late adopters (Stiglitz 2000). Further, some organizations theory anticipates reduced performance among late adopters, who adopt in response to social pressures rather than performance opportunities (DiMaggio and Powell 1983, Ingram and Silverman 2002, Ansari, Fiss, and Zajac 2010, Kennedy and Fiss 2009).

In some sense, efficiency may increase due to learning. During the study period, these technologies became more affordable and availability, individuals and organizations gained experience and understanding using them, and building codes advanced. These all suggest an improved technical fit between practice and its adaptation (Ansari, Fiss, and Zajac 2010). Yet from Figure 2 we observe that this is an incomplete picture of the overall trends in certification pathways. Numerous green building technologies diffused rapidly during this period, becoming widely available and more cost-effective, yet not all become more popular. Some such technologies, such as construction waste management, were not available to early adopters, who innovated green building techniques and practices to gain certification, stimulating market supply of those practices for future adopters (Simcoe and Toffel 2014).

Those technologies which should have diffused due to learning, but which did not become more prevalent in LEED certification pathways vary systematically from those that did become part of the dominant pathway. Those which become more popular are all directly associated with a clearly measurable private benefit from efficiency. Those which do not become more popular are either purely public goods, or offer only indirect or intangible benefits to the building owner. Though LEED scores increase over time, and though the label appears to induce improvements (Matisoff, Noonan, and Mazzolini 2014) to energy efficiency (Asensio and Delmas 2017), the data show that the label may not effectively incentivize public good provision.

The LEED label aims to improve environmental outcomes by providing a complex mechanism that distinguishes quality and bundles market rents to public good provision. Although improvements in some green building practices are observed, this growth does not occur in all dimensions. A more extensive adaptation of LEED certification would emphasize public benefits more than what is observed in the data. From a policy and public economics perspective, it may be worth investigating how market and information programs like LEED can be improved to provide these types of benefits.

5.8 Verifying Intangibles… and Tangibles

From Figure 2, most sets of expectations demonstrate mixed results. If LEED certification is pursued to address concerns for biodiversity, occupant health, or labor conditions, it does not appear that the emergent or dominant form of the certification pathway meets these goals. This gap has been noted extensively by critics, who might assert that “LEED is just a regular building with a bike rack” to suggest the label does not achieve some more fundamental goal, or that certification is merely symbolic greenwashing. Yet notably, the adoption of bike racks toward LEED certification becomes less popular over time.

In fact, the visible demonstrations of green quality are relatively more popular among early adopters compared to latecomers. This is true of each visible LEED credit, with two exceptions, both related to reducing energy use. That early adopters feel the need to tangibly demonstrate building qualities above and beyond certification is puzzling. Typically, certification is used to verify improvements that cannot be observed by the consumer, labels inform consumers about qualities they will experience once using the good, and directly observable qualities require neither of these strategies. Green roofs, solar panels, and large windows for daylighting are all quite conspicuous. Why would early adopters choose to verify tangible improvements?

A plausible explanation arises from demand-side learning: early adopters certify despite low recognition and understanding of the label. When this is the case, the label cannot alone credibly verify environmental quality, and early adopters must ensure understanding by visibly distinguishing the product. As the practice diffuses and recognition grows, adopters are less dependent on visibility and may instead rely on the elite status established by early adopters and conferred by the certification (Potoski and Prakash 2009).

5.9 Learning, or Locking-In?

Whereas early adopters certify through practices that don't call for verification, late adopters certify through practices that oughtn't require incentives from market premiums. Energy efficiency has numerous benefits independent of certification (Allcott and Greenstone 2012). Moreover, early adopters provided innovations and stimulated supply-side spillovers that made some credits more plausible, more accessible, and more affordable, which did not become integrated with the dominant certification pathway. Though some learning appears at play, this learning seems to be concentrated among early innovators, without strong implications for later replicators.

The emergence of dominant LEED certification pathways is characteristic of a lock-in effect in which practices are replicated without the optimization assumptions of technology choice. From the data, we observe greater adoption of LEED certification, but not more production of public benefits. Yet the flexible certification program design was intended to provide room for customization and innovation, and to avoid such lock-in.

This challenges the preference for flexible, voluntary, and market-based approaches as policy tools for environmental management that avoid the Pareto inefficiencies that arise from technology lock-in (Keohane, Revesz, and Stavins 1998, Stavins 1998). While increased efficiency is generally desirable, it is not clear that this outcome was intended when the program began. Because sustainability is a multifaceted goal, it is not clear whether LEED buildings are getting greener, or just "LEEDier."

The increased adoption without substantive contribution to public goods is consistent with decoupling literature that anticipates more symbolic management (Ingram and Silverman 2002, Powell and DiMaggio 1991) as adopters respond to social pressures (DiMaggio and Powell 1983). Over time, real estate investment trusts may have pressured builders toward adoption, and, numerous policies have popped up at the local level to coerce builders toward more sustainable practices. Given these pressures, the extent to which certification is voluntary is not clear, and may impact the types of impacts realized through the program.

5.10 Conclusion

The analysis above identifies the emergence of dominant practices toward LEED certification. An understanding of how certification is obtained can help us understand how well the program works in reaching its goals. In this case, the flexibility with which LEED addresses multifaceted goals presents challenges to measuring progress. By opening the "black box" of adoption, we can observe that private benefits from efficiency measures are increasingly adopted, though this growth appears to come at the expense of public benefits, despite bundling public goods to private market returns (Kotchen 2006, 2013) from certification and signaling (Matisoff, Noonan, and Mazzolini 2014). The complexity of LEED's approach leaves open this possibility, though the approach appears adept at mitigating other market failures. How can public good provision be stimulated, when it is entangled with other market failures? Some of the world's greatest challenges involve such complex aims (Durant 2004). Future policy innovations provide answers this question.

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CHAPTER 6: CONCLUSION

In the preceding chapters, I present evidence regarding the adaptation of green building certification pathways to different market sectors over time. Data suggest that firms are more willing to invest in energy efficiency in order to reach higher signaling tiers, and learn to implement efficiency practices more extensively over time, especially in the private sector. Despite some notions that LEED as a noisy signal should wane in effectiveness, the number of buildings choosing to certify within the program grows each year. Moreover, it appears that certification increases in extensiveness and fidelity each year. This suggests that a Race to the Top may be occurring, at least with regard to some components of the green building movement. The results suggest an evolution of practices that increasingly depend on private benefits, consistent with the notion of sustainability as supporting the triple bottom-line.

Methodologically, this dissertation opens the black box of practice adoption to advance our ability to measure marketing as a distinct from environmental performance. Relaxing the assumption that fidelity is orthogonal to extensiveness, I present an alternative framework for practice adaptation, which proves useful in understanding noisy green signals. In doing so, I advance signaling theory to accommodate the idea that signals may be tuned to specific stakeholder interests. This nuanced view of signaling theory synthesizes the existing economic perspective with past work on corporate responsibility and organizations. Though the literatures were previously disjointed, this dissertation presents a unified framework of green signals.

In each chapter, I investigate green signaling trends in LEED certification, drawing on two central measures of practice adaptation: extensiveness and fidelity. Though I generally measure these as public good provision and performance motivation, I relax the relationship between the measure and the concept in the final chapter. This allows us to question the extent to which certification meets the original aim of the green building movement. As discussed, the answer to this question is highly normative, and in some ways a matter of philosophy rather than empirics. However, this question points to a key next step in the thread of presented empirical research.

Noting the ambiguity with which the certification pathways in available data appear to meet the goals of the green building movement (Chapter 5), it stands to reason that the goals of green building policies may or may not be met. In response to this question, I've constructed a database of green building policies across the United States. These vary immensely in terms of their stringency, scope, and focus (Matisoff, Noonan, and Flowers 2016), but each is explicit about its goal(s). Green building certification pathways can be examined before and after each policy at a local level, comparing the original aim to the ultimate result. From a policy evaluation perspective, this presents an opportunity for a large-N study of local sustainability initiatives. From a management perspective, this stands to confer deeper understanding of means-ends decoupling under circumstances of adoption that are voluntary, coerced, and incentivized. A comparison of trends in certification pathways to policy drivers of certification may reveal how coercion influences fidelity in practice adaptation, a direct test of past theoretical propositions (Ansari, Fiss, and Zajac 2010).

Adaptation fidelity is one central dimension of the research presented and anticipated thus far; adaptation extensiveness is another. A key challenge to the assessment of voluntary program adoption is the role that adopters play in diffusing practices to their neighbors (Matisoff 2015). In the case of green building certifications, peer effects seem to have played a major role in diffusing practices to non-adopters (Simcoe and Toffel 2014). While in some ways it appears adoption becomes more extensive over time (Chapter 4), a variety of organizational perspectives suggest diminished extensiveness over time (Ansari, Fiss, and Zajac 2010). A critical component of our understanding in this matter is the role that networks play in diffusing best practices. This is suggested by some literature (Owen-Smith and Powell 2004, Prakash and Potoski 2006, Saikawa 2013), and in the dissertation (Chapter 4), but is not treated in a general sense. By leveraging building certification trends across metro-area markets, it is possible to observe how individual building owners carry practices from one network to another, stimulating practice adoption. Further, the clustering of individual LEED credits within these markets may be useful in observing the adaptation of practices over time. This approach builds on insights developed in Chapter 4, which suggests that voluntary programs may be a catalyst for market transformation.

The signaling and learning perspective on Racing suggests a potential for information programs to be increasingly exploited into a Race to the Bottom (Chapter 4). In the weak form, this occurs when organizations may overstate their performance, capitalizing on market benefits of green signals without substantive environmental performance improvement. The strong form, more alarmingly, suggests that the standards themselves may be manipulated to diminish both fidelity and extensiveness of practice adaptation over time. This is premised on the notion of regulatory gaming of voluntary standards (Maxwell, Lyon, and Hackett 2000), a case of "regulatory capture" in which non-state governance fails to induce legitimacy (Bernstein and Cashore 2007). The extent to which a voluntary program may be captured by non-state governance structures is critical to the successful diffusion of the voluntary program (Darnall, Potoski, and Prakash 2009), but has not been addressed in a longitudinal setting capable of revealing shifts in the legitimacy of a standard-setting body. The decision-making processes within non-state governing bodies draws important questions about the legitimacy of the standards they produce; more generally, it is not clear that the institutions they represent are democratically supported, pointing to further areas of normative investigation.

6.1 References

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